National Park Service
U.S. Department of the Interior

Denali National Park
Acoustic Monitoring Report - 2008

ON THE COVER
Highpower Creek Looking Toward Mt. McKinley
NPS Photo

Denali National Park
Acoustic Monitoring Report - 2008

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Contents

Figures

Tables

Executive Summary

Park staff deployed five acoustic monitoring systems in Denali National Park in 2008 (see Table 1). The purpose of this monitoring effort was to continue to gather data inventorying the current acoustic conditions and level of aircraft operations as called for in the 2006 Denali Backcountry Management Plan. The collected data included existing ambient, natural ambient, percent time audible, and loud acoustic event statistics for intrinsic and extrinsic sound sources. They also serve as a permanent record of existing acoustical conditions in the summer of 2008. Systems were deployed for thirty days to log one-second sound pressure levels and interval audio recordings.

Table 1. Sites sampled in 2008

Site Location	Elevation (meters)	Latitude	Longitude	Sampling Period
DENAHICR: Highpower Creek	639	63.08447	-152.05722	June 2 – June 26
DENATKAH: Toe of Kahiltna Glacier	820	62.54195	-151.30338	Aug 9 – Aug 17
DENATOKO: Toe of Tokositna Glacier	273	62.66451	-150.79065	Aug 17 – Sept 12
DENAUPWC: Upper Wigand Creek	883	63.25249	-151.24640	July 23 – July 25 & Aug 25 – Sept 16
DENAUSLC: Upper Slippery Creek	639	63.76028	-149.98921	July 23 – Aug 10

Table 2 shows existing and natural ambient statistics in dBA and average percentage of time audible, number of events per day, and maximum sound pressure level (SPL) for aircraft sound sources, which are the most prominent extrinsic sound at these sites. Median existing ambient (L_{50}) describes the acoustical environment as is, including both natural and extrinsic sounds. Natural ambient (L_{nat}) estimates what the acoustical environment might sound like without the contribution of extrinsic sounds. This table also shows exceedence metrics L_{10} and L_{90}, which essentially mark the average maximum and minimum exceedence levels over the monitoring periods. When interpreting sound pressure level data, it should be noted that the decibel scale is logarithmic. As such, a 3 dB increase in sound pressure level is actually a doubling of sound energy. Overall, the acoustic conditions of these 2008 sites varied. The Highpower Creek site was the quietest in both ambient and natural ambient. Very low levels of aircraft activity were observed. The Tokositna Glacier site experienced the greatest natural ambient because of the presence of the sound of water exiting the glacier, but also had the highest amount of aircraft activity.

Table 2. Median natural and existing ambient and mean aircraft statistics for all sites

Site Name	L_{nat}	L_{10}	L_{50}	L_{90}	% Aircraft	# Aircraft/Day	Aircraft Max SPL
Highpower Creek	23.1	27.8	23.1	21.8	0.36	2.1	43.5
Toe of Kahiltna Glacier	28.8	38.9	29.1	24.7	2.25	12.3	53.8
Toe of Tokositna Glacier	41.3	42.7	41.4	40.4	5.08	28.9	51.7
Upper Wigand Creek	23.7	26.7	23.8	22.4	2.66	13.6	39.4
Upper Slippery Creek	26.3	31.2	26.5	24.2	3.89	20.9	37.4

Introduction

Natural sound is both a resource in its own right as well as an important aspect of Denali's wilderness resource values, and the influence of motorized noise on visitor experience is a key concern throughout the park. Denali's Backcountry Management Plan (BCMP), finalized in 2006, established indicators and standards for the natural sound environment and called for monitoring to evaluate whether the standards are being satisfied. Soundscape measurements are objective and employ methods that are easily reviewed by the public, which will provide strong support for future management decisions. Without these data the park will have little information to make management guidelines or support management decisions that may affect the quality of the Park's soundscape.

The initial push for Denali to begin soundscape inventories began with Director's Order 47 (DO-47). Robert Stanton issued the order in 2000 directing park managers to identify baseline soundscapes and related measures. DO-47 states that "natural sounds are intrinsic elements of the environment that are often associated with parks and park purposes…They are inherent components of 'the scenery and the natural and historic objects and the wild life' protected by the NPS Organic Act." DO-47 directed park managers to "(1) measure baseline acoustic conditions, (2) determine which existing or proposed human-made sounds are consistent with park purposes, (3) set acoustic management goals and objectives based on those purposes, and (4) determine which noise sources are impacting the park and need to be addressed by management." Furthermore, it requires park managers to "(1) evaluate and address self-generated noise, and (2) constructively engage with those responsible for other noise sources that impact parks to explore what can be done to better protect parks."

The primary purpose behind the Denali soundscape study has been to measure the level of influence overflight traffic and snowmachine traffic has on the Park's soundscape. Understanding the natural soundscape is important to evaluate the level of impact human-generated sounds may have on this important resource. Different habitats have specific soundscape characteristics that are an important attribute of the natural system, with distinct impacts on the human perception of the environment. The natural soundscape is generally comprised of two main sound categories, physical and biological. Physical sounds are created by physical forces (wind, rock fall, rivers, etc.), whereas biological sounds are created by organisms (birds, frogs, plants, etc.). The presence and abundance of sounds from these two categories is used to characterize different habitats. Impacts on the natural soundscape and on visitor experiences come from human-generated sounds.

Soundscape Planning Authorities

The National Park Service Organic Act of 1916 states that the purpose of national parks is "… to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." In addition to the NPS Organic Act, the Redwoods Act of 1978 affirmed that, "the protection, management, and administration of these areas shall be conducted in light of the high value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided by Congress."

Direction for management of natural soundscapes[1] is represented in 2006 Management Policy 4.9:

> The Service will restore to the natural condition wherever possible those park soundscapes that have become degraded by unnatural sounds (noise), and will protect natural soundscapes from unacceptable impacts. Using appropriate management planning, superintendents will identify what levels and types of unnatural sound constitute acceptable impacts on park natural soundscapes. The frequencies, magnitudes, and durations of acceptable levels of unnatural sound will vary throughout a park, being generally greater in developed areas. In and adjacent to parks, the Service will monitor human activities that generate noise that adversely affects park soundscapes [acoustic resources], including noise caused by mechanical or electronic devices. The Service will take action to prevent or minimize all noise that through frequency, magnitude, or duration adversely affects the natural soundscape [acoustic resource] or other park resources or values, or that exceeds levels that have been identified through monitoring as being acceptable to or appropriate for visitor uses at the sites being monitored (NPS 2006a).

It should be noted that "the natural ambient sound level—that is, the environment of sound that exists in the absence of human-caused noise—is the baseline condition, and the standard against which current conditions in a soundscape [acoustic resource] will be measured and evaluated" (NPS 2006b). However, the desired acoustic condition may also depend upon the resources and the values of the park. For instance, "culturally appropriate sounds are important elements of the national park experience in many parks" (NPS 2006b). In this case, "the Service will preserve soundscape resources and values of the parks to the greatest extent possible to protect opportunities for appropriate transmission of cultural and historic sounds that are fundamental components of the purposes and values for which the parks were established" (NPS 2006b).

Sampling Plan

Denali's soundscape sampling plan is designed using a coarse grid derived from the Long Term Ecological Monitoring (LTEM) grid. The number of points in the coarse grid is driven by the number of stations available per year (5) and the length of time each station should be established at each location. To properly characterize the natural soundscape, stations should be established such that at least one month of continuous data is collected at each site during the field/tourist season (beginning of July to the end of August (one station may be established during the winter months during some years and the shoulder seasons will be attempted at limited locations)). To maximize the spatial coverage with only five stations it was decided to sample two locations through the entire field season, while rotating three stations over two sites each – two months as each site. Two of the two month-long sites would be established for the coarse sampling grid with two free to allow park managers to collect data at sites of specific interest. As such, six LTEM grid locations will be sampled each year, with 60 grid points to be sampled overall (Figure 1).

[1] The 2006 Management Policy 4.9 and related documents refer to "soundscapes" instead of "acoustic resources." When quoting from this authority, it is advisable to note that the term often refers to resources rather than visitor perceptions.

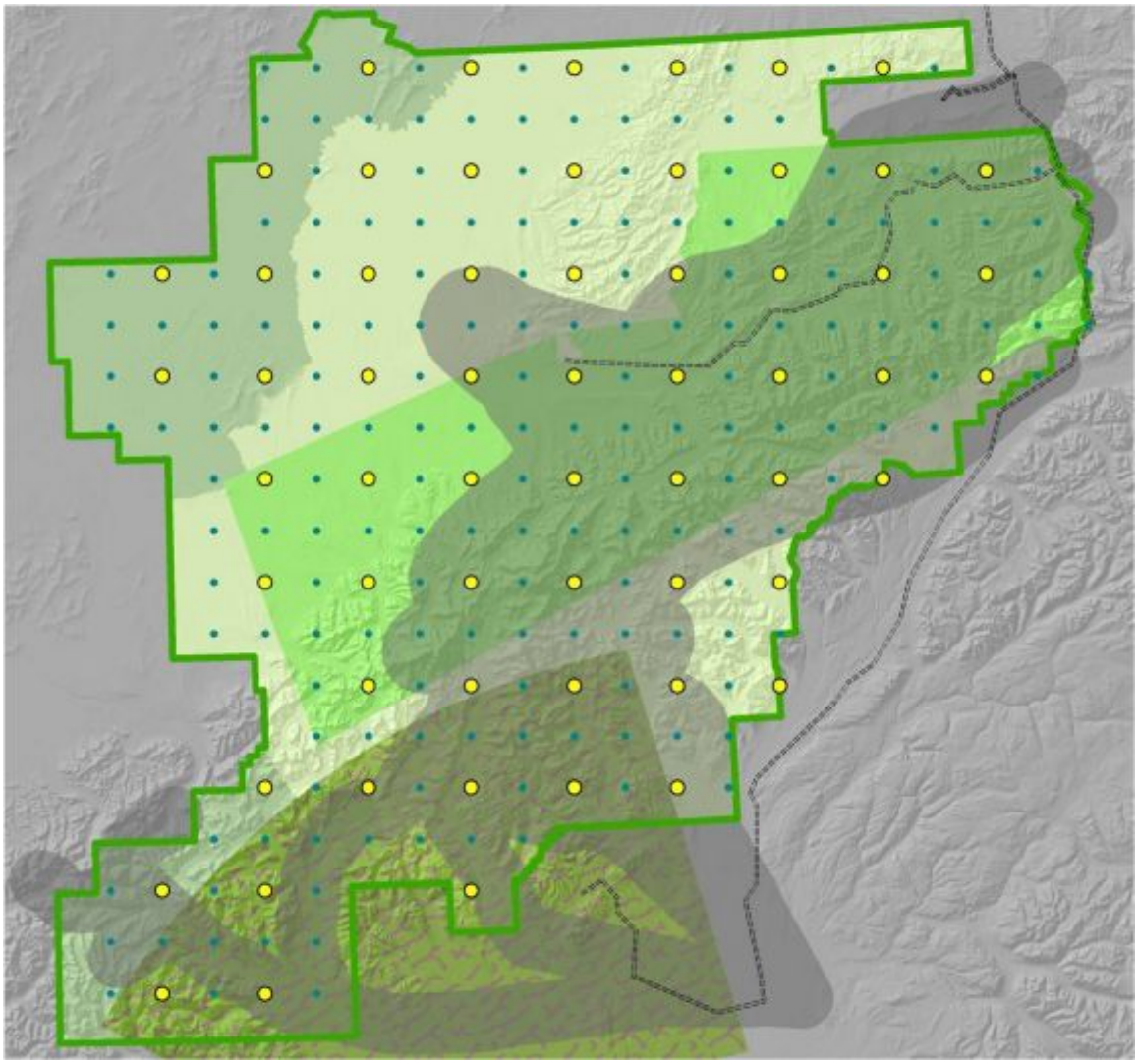

Figure 1. Map showing the coarse grid of sixty points to be sampled.

Study Area

Park staff deployed five acoustic monitoring systems in Denali National Park in 2008.

Table 3. Sites sampled in 2008

Site Location	Elevation (meters)	Latitude	Longitude	Sampling Period
DENAHICR: Highpower Creek	639	63.08447	-152.05722	June 2 – June 26
DENATKAH: Toe of Kahiltna Glacier	820	62.54195	-151.30338	Aug 9 – Aug 17
DENATOKO: Toe of Tokositna Glacier	273	62.66451	-150.79065	Aug 17 – Sept 12
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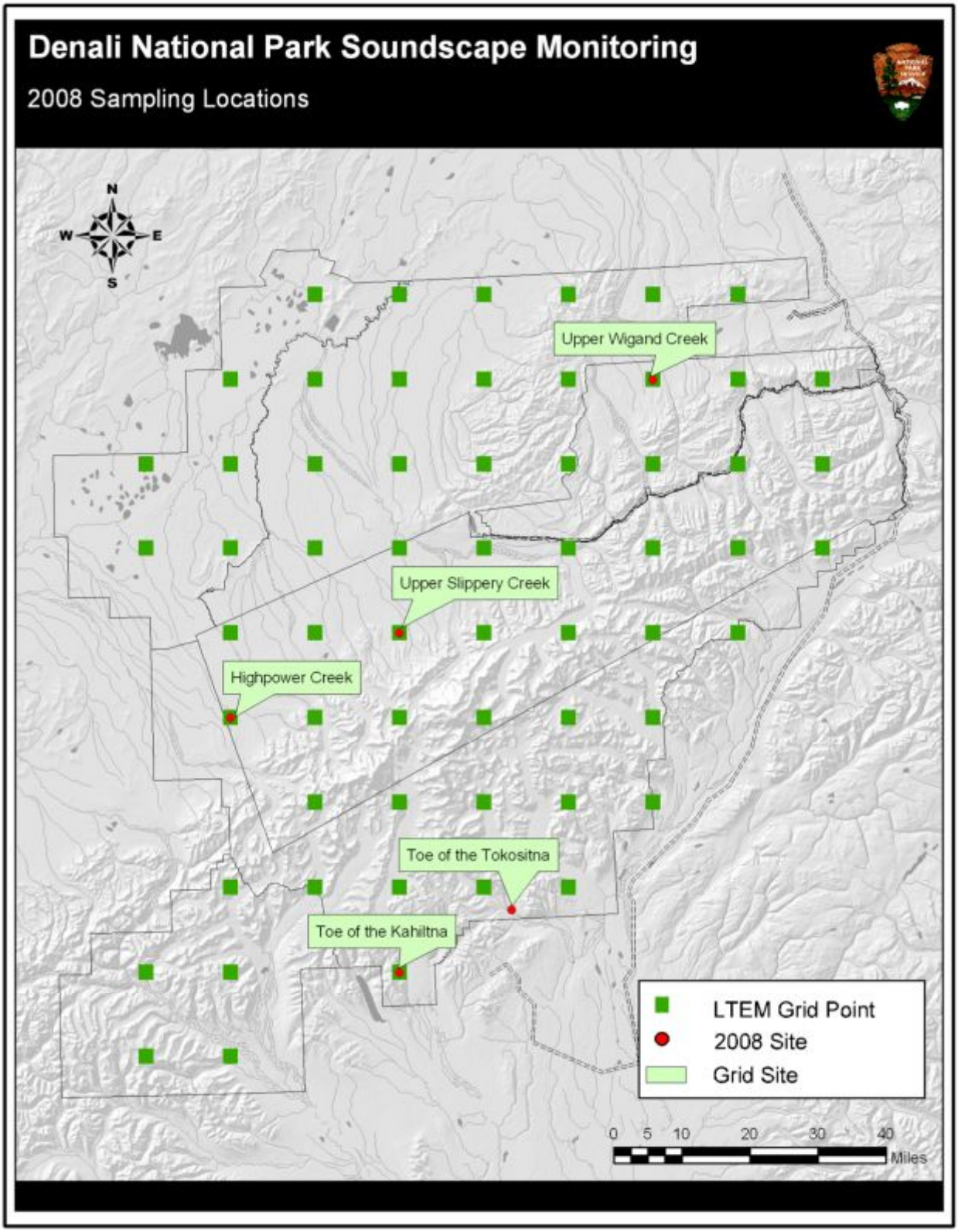


Figure 2. 2008 Acoustic monitoring sites in Denali National Park.

Methods

Automatic Monitoring

The Larson Davis 831 sound level meter (SLM) is a hardware-based, real-time analyzer which constantly records one second sound pressure level (SPL) and 1/3 octave band data, and exports these data to a USB storage device. These Larson Davis-based sites met American National Standards Institute (ANSI) Type 1 standards.

Each Larson Davis sampling station consisted of:

- Microphone with environmental shroud and Rycote windscreen
- Preamplifier
- Solar panel and batteries
- Anemometer

Each acoustic sampling station collected:

- SPL data in the form of A-weighted decibel readings (dBA) every second
- Interval digital audio recordings: 5 seconds every 5 minutes
- 1/3 octave band data every second ranging from 12.5 Hz – 20,000 Hz

Visual Analysis

For each monitoring site, staff visually analyzed a subset of SPL samples (fifteen days) in order to identify durations of audible sound sources. See Appendix C for further information on visual analysis. Hourly time audible statistics are then inserted into a formula which produces natural ambient sound level estimates (see Calculation of Metrics below). The total percent time extrinsic sounds were audible was then used to calculate the natural ambient sound level.

Audibility Analysis

For each monitoring site, staff analyzed a subset of audio samples (every other day of the site occupation) to identify natural and quiet sound sources which are difficult to reliably identify though visual analysis. Listening headphones were calibrated with a 94dB, 1000Hz tone which was recorded at the time of data collection, and approximates a playback volume similar to what would be heard if the observer were actually listening at the sample site. This audibility data results in an estimate of total percent time audible and makeup of the natural components of the soundscape.

Calculation of Metrics

Several metrics are calculated in order to provide some detail about the characteristics of the acoustical environment. The current status of the acoustical environment can be characterized by a number of measurements including sound levels across the 1/3 octave band spectrum (from 12.5 Hz to 20,000 Hz), overall sound levels, and percent time audible durations for various sound sources. Two fundamental descriptors of the acoustical environment are existing and

natural ambient sound levels which are presented as exceedence levels (L_x). They represent the dBA exceeded x percent of the time during the given measurement period. For example, measured in dBA, the existing ambient (L_{50}) is the sound level exceeded 50% of the time, or median sound level. It is the uncensored composite of all sounds at a site, both human caused and natural. L_{10} and L_{90} are also presented which describe the sound levels exceeded 10% and 90% of the time, respectively.

The natural ambient estimates the acoustic environment without the contribution of anthropogenic sounds. The differences between L_{50} and L_{nat} values allow NPS to answer the following questions:

1. What are the listening opportunities in the absence of human development and activities?
2. How are these listening opportunities compromised by increased sound levels due to noise?

To calculate L_{nat}, the following method is utilized:

- NPS staff calculate the percentage of all samples containing extrinsic sounds for each hour of the day (P_H) by either listening to samples, or visually analyzing daily spectrograms.
- P_H is used to complete this formula for every hour: $x = \frac{1 - P_H}{2} + P_H$
- Hourly x_H values are entered into a database of all octave band information.
- Example: if extrinsic sounds are audible 50% of the time (P_H =0.5), then x_H is 0.75.
- L_{nat} is computed as the sound level that is exceeded 100*x_H percent of the time.
- (In practice, L_{nat} is calculated by sorting the relevant sound level measurements and using x_H to extract the appropriate order statistic).

This procedure approximates the sound levels that would have been measured in the absence of extrinsic noise. The procedure is guaranteed to produce an estimate that is equal to or below the existing ambient sound levels, and the results of this calculation have produced consistent results at most backcountry sites analyzed by the NPS Natural Sounds Program.

Results

The following summaries and figures represent the reduced data for each of the 2008 sites. These include percent audibility for natural sounds and mechanized noise, hourly natural ambient and exceedence sound levels, and figures which speak directly to the soundscape indicators and standards outlined in Denali's Backcountry Management Plan: percentage of time audible, number of events per day, and maximum sound pressure levels. A separate section is devoted to each site, and should be considered a comprehensive site profile for Park purposes.

Highpower Creek

Location Description: located approximately halfway between Highpower Creek and Old Park Boundary Marker M2159.

Purpose/Project: Location randomly chosen from the LTEM grid as part of the long-term Denali Soundscape inventorying and monitoring plan.

Coordinates: Lat. 63.08447, Long. -152.05722 Elevation: 639 Meters

Time at Location: 2-June-2008 – 26-June-2008

BCMP Management Zone: Low Park Ecoregion: Glaciated Uplands

Access: Helicopter

Summary: The purpose of the Highpower Creek location was to collect data at one of the long-term ecological monitoring (LTEM) grid points, as outlined in the above sampling plan. LTEM grid point #86 was stratified as an Old Park (designated Wilderness) location and randomly selected from all locations requiring aircraft access.

The most commonly heard natural sounds at this site were birds (audible 55% of the time), wind (51%), insects (21%), and rain (10%). Mechanized sound was audible 0.3% of the time on average. Conditions exceeded the BCMP percent audible standard 1% of the time, number of events per day 40% of the time, and maximum SPL 70% of the time.

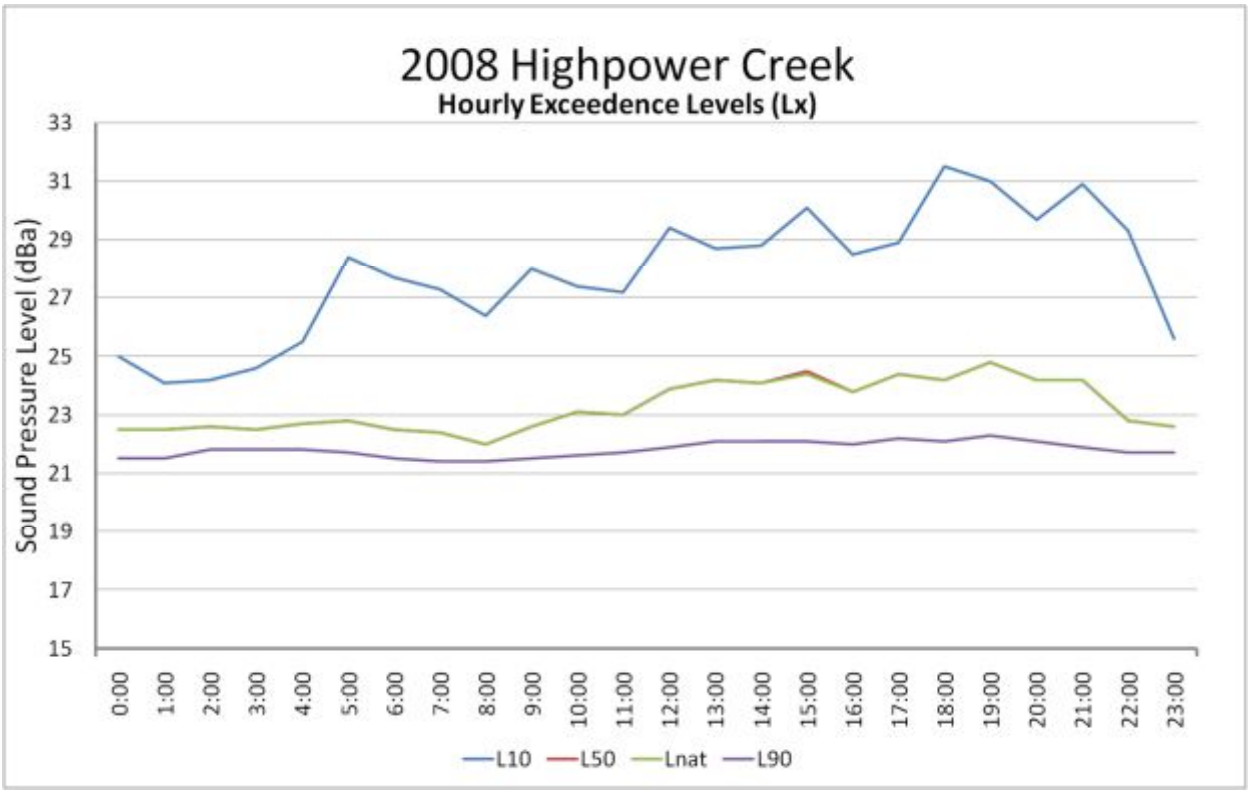


Figure 3. Exceedence levels for Highpower Creek

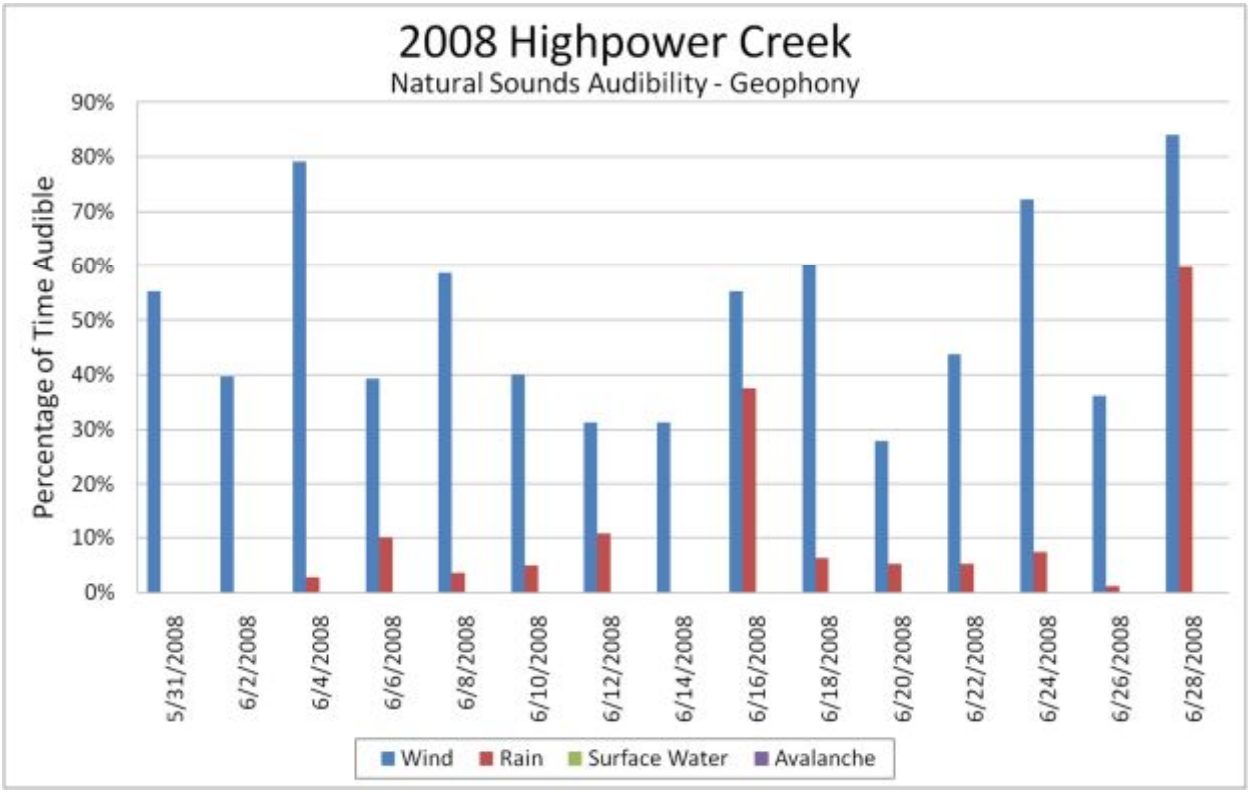


Figure 4. Percentage of time audible for geophonic sounds at Highpower Creek.

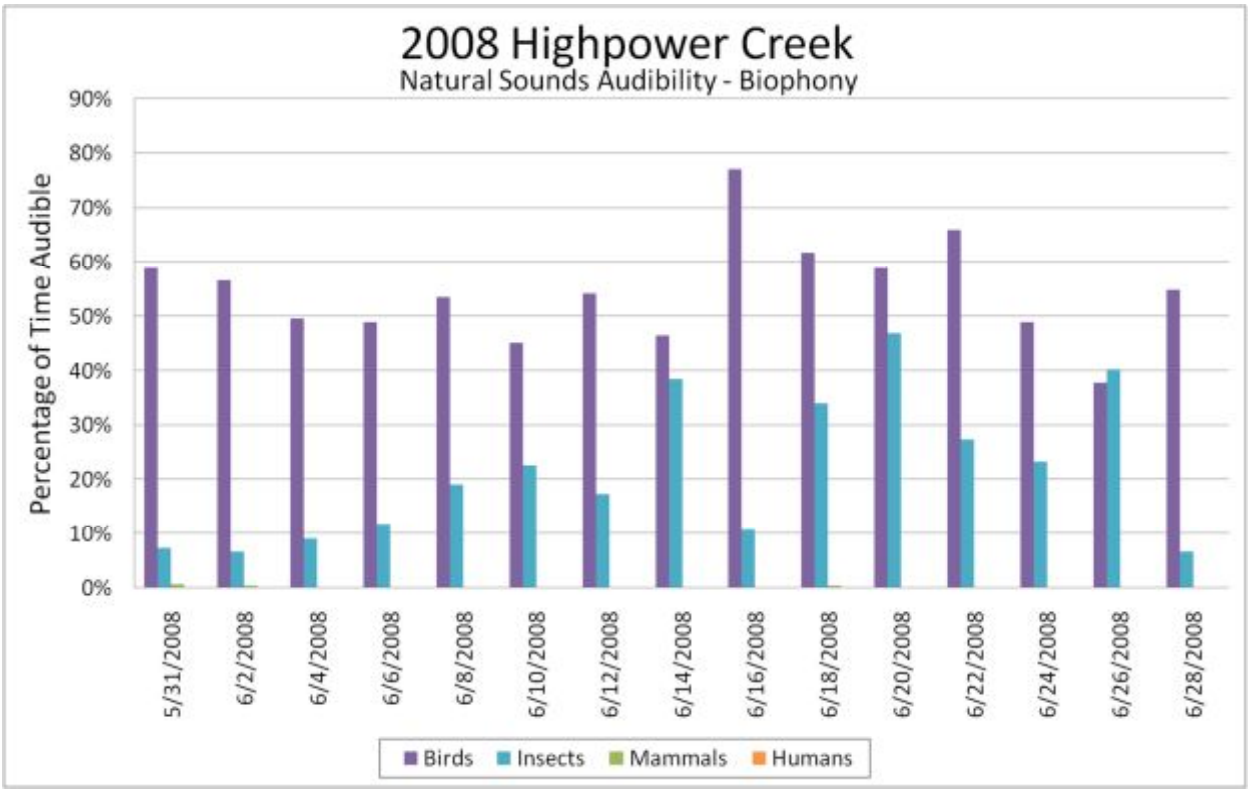


Figure 5. Percentage of time audible for biophonic sounds at Highpower Creek.

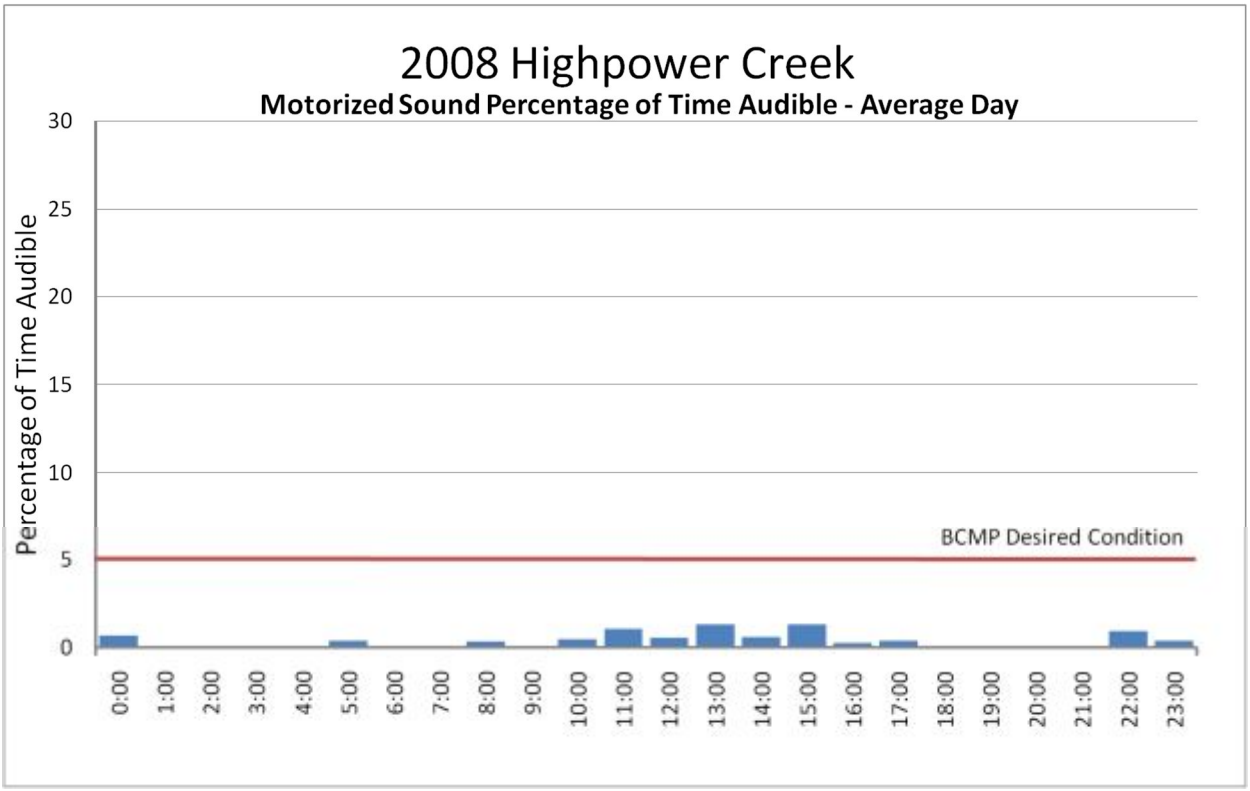


Figure 6. Audibility of mechanized noise for an average day, by hour, at Highpower Creek.

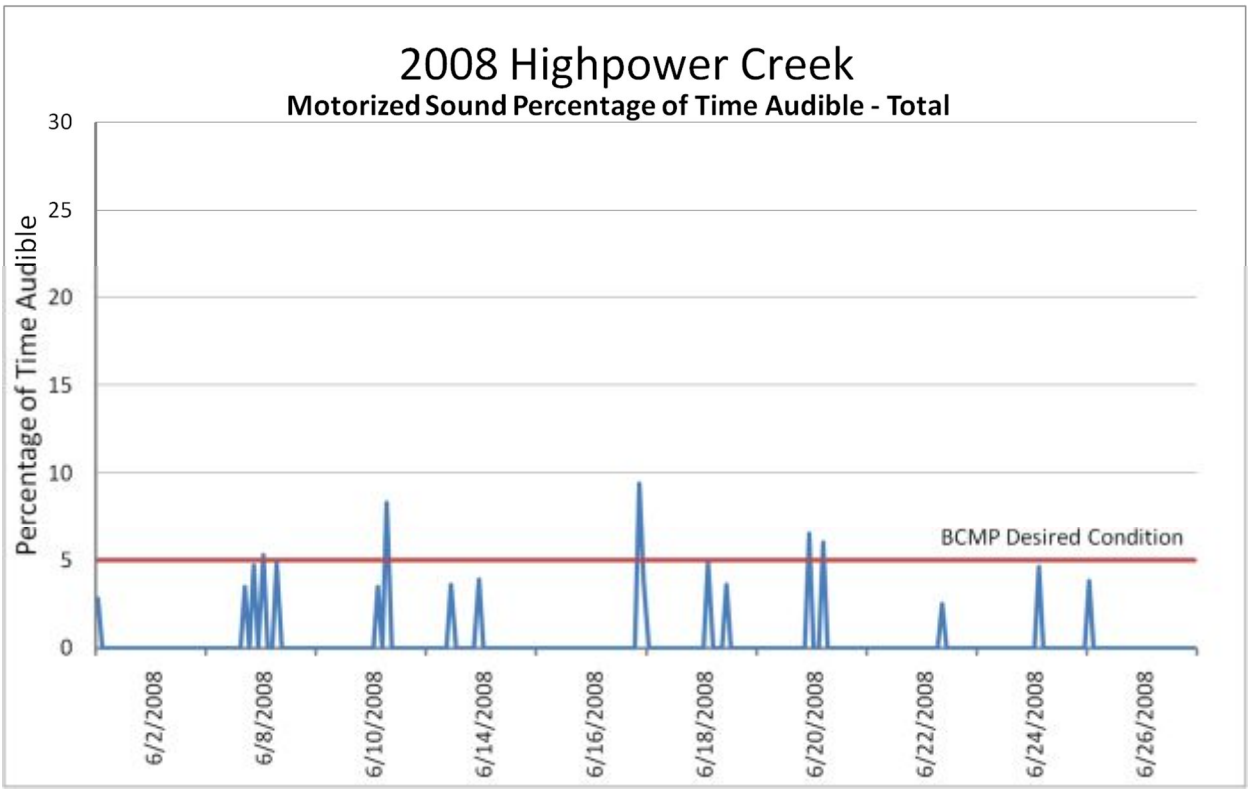


Figure 7. Audibility of mechanized noise at Highpower Creek.

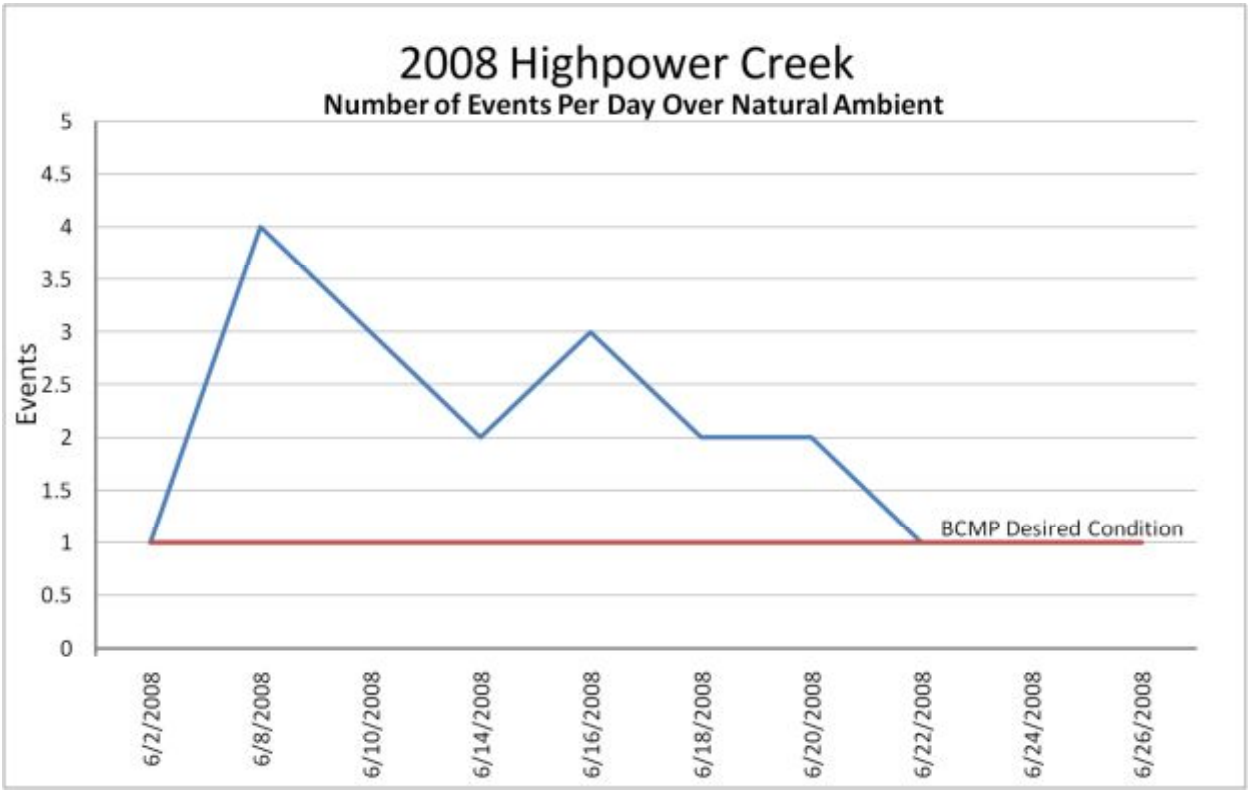


Figure 8. Number of mechanized noise events identified per day at Highpower Creek.

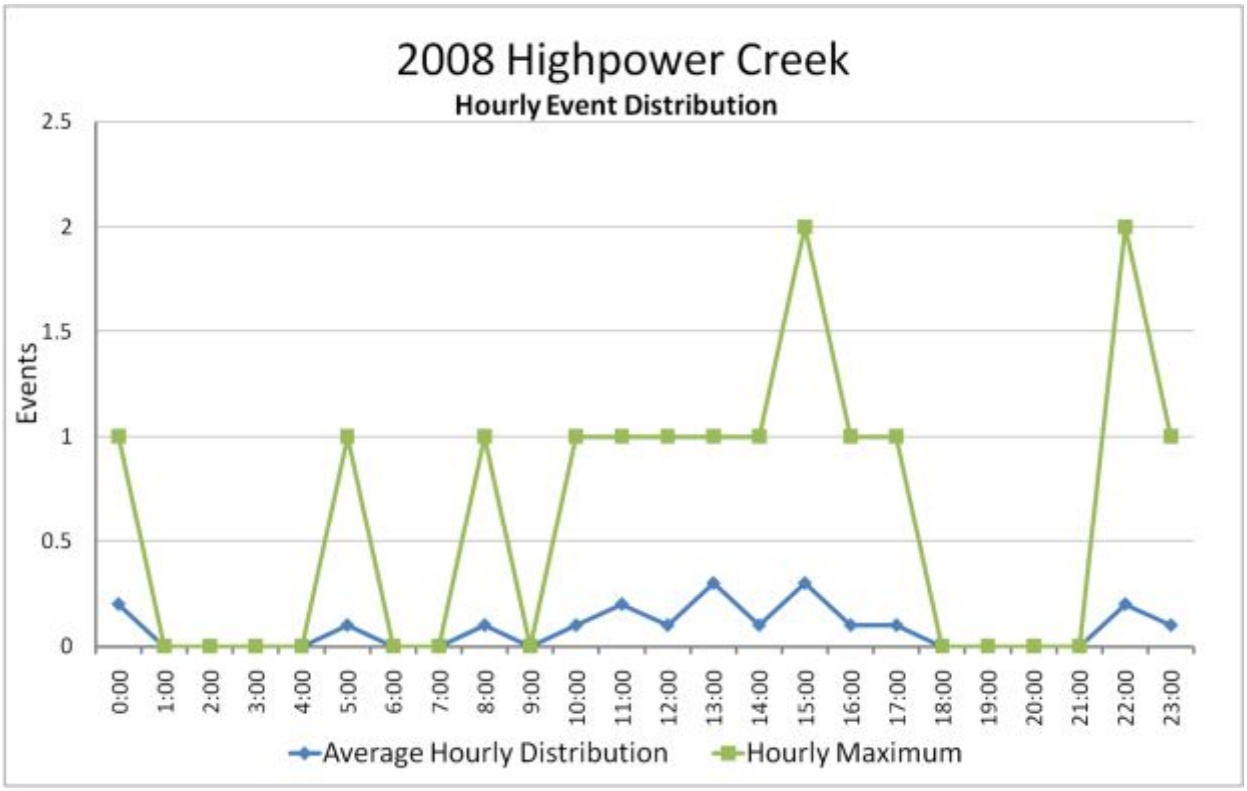


Figure 9. Hourly average and maximum mechanized event distribution at Highpower Creek.

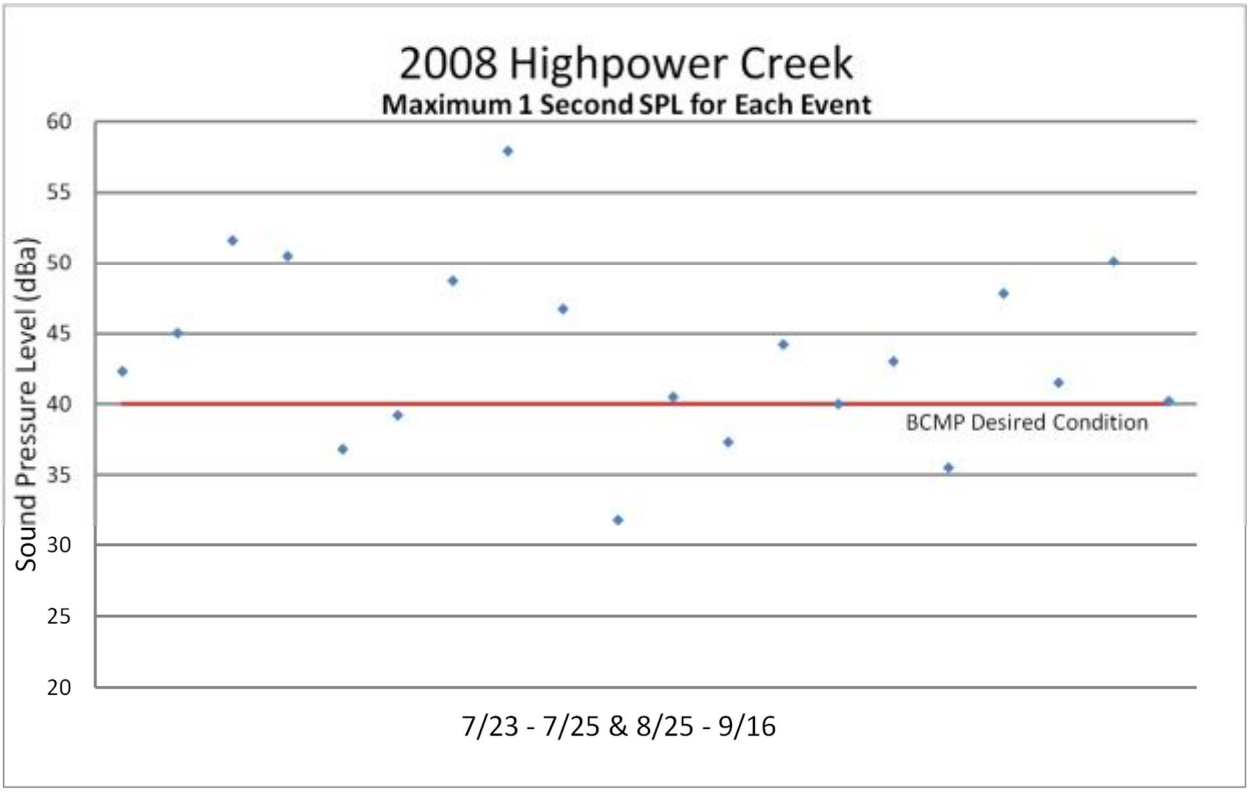


Figure 10. Maximum 1 second SPL for each mechanized event identified at Highpower Creek.

Toe of the Kahiltna Glacier

Location Description: located on the west bench of the Toe of the Kahiltna Glacier.

Purpose/Project: Location randomly chosen from the LTEM grid as part of the long-term Denali Soundscape inventorying and monitoring plan.

Coordinates: Lat. 62.54195, Long. 151.30338 Elevation: 820 Meters

Time at Location: 13-June-2008 – 19-August-2008

BCMP Management Zone: Medium Park Ecoregion: Subalpine Mountains

Access: Helicopter

Summary: The purpose of the toe of the Kahiltna Glacier location was to collect data at one of the long-term ecological monitoring (LTEM) grid points, as outlined in the above sampling plan. LTEM grid point #18 was stratified as an Old Park (designated Wilderness) location and randomly selected from all locations requiring aircraft access.

The most commonly heard natural sounds at this site were wind (audible 18% of the time), rain (15%), birds (10%), and insects (7%). Mechanized sound was audible 2.25% of the time on average. Conditions exceeded the BCMP percent audible standard 2% of the time, number of events per day 30% of the time, and maximum SPL 87% of the time.

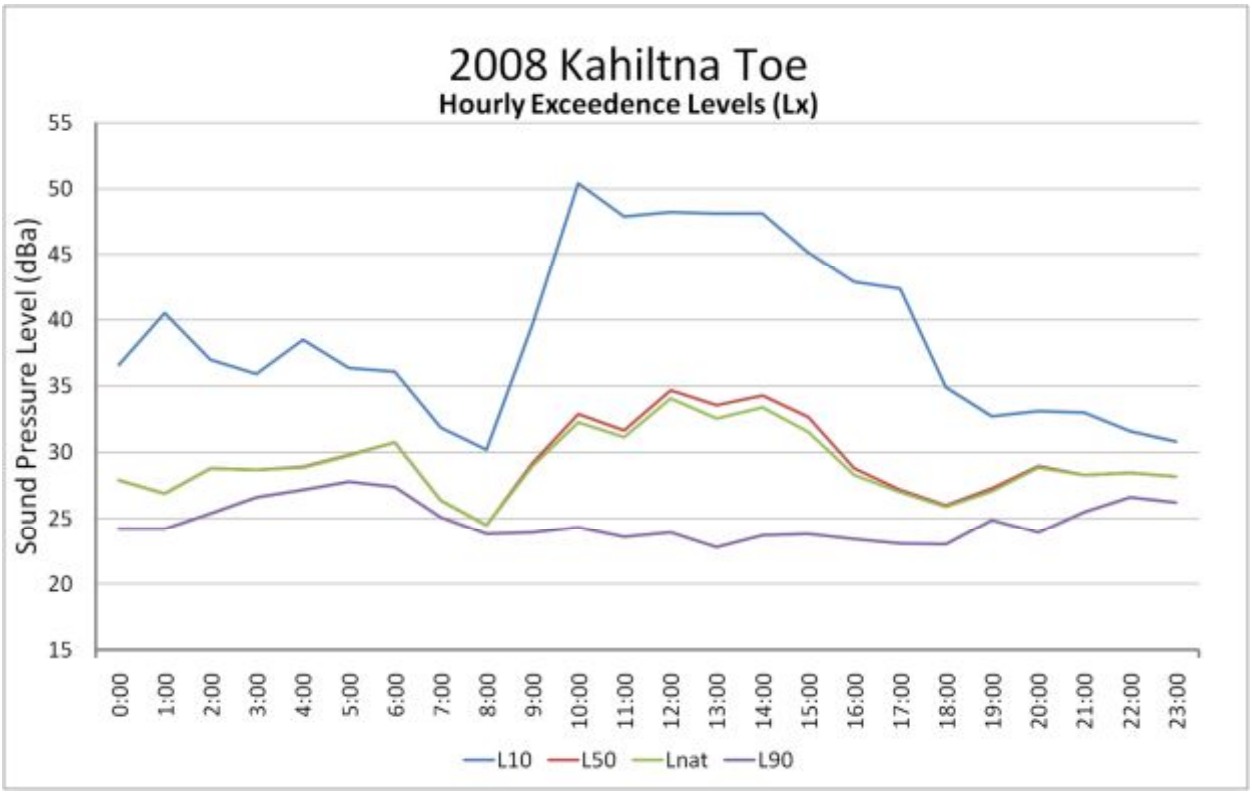


Figure 11. Exceedence levels for Toe of the Kahiltna Glacier.

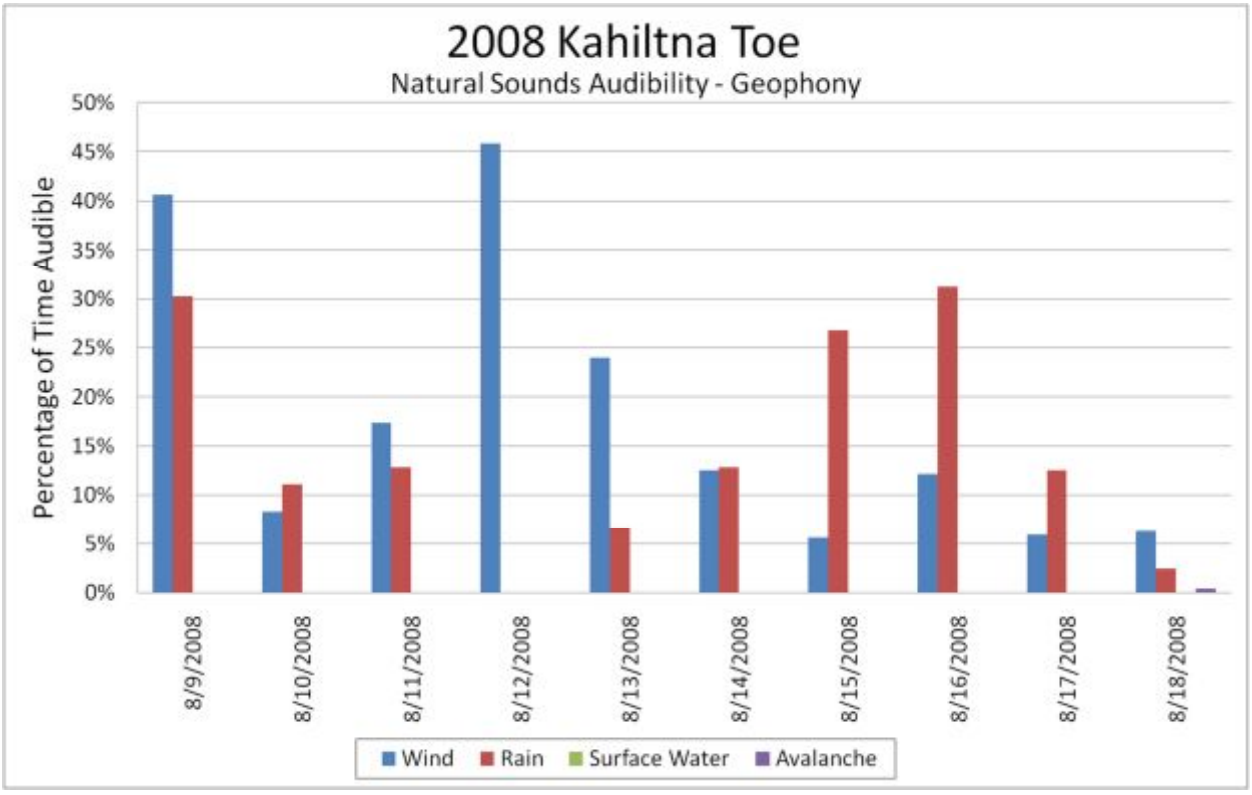


Figure 12. Percentage of time audible for geophonic sounds at Toe of the Kahiltna Glacier.

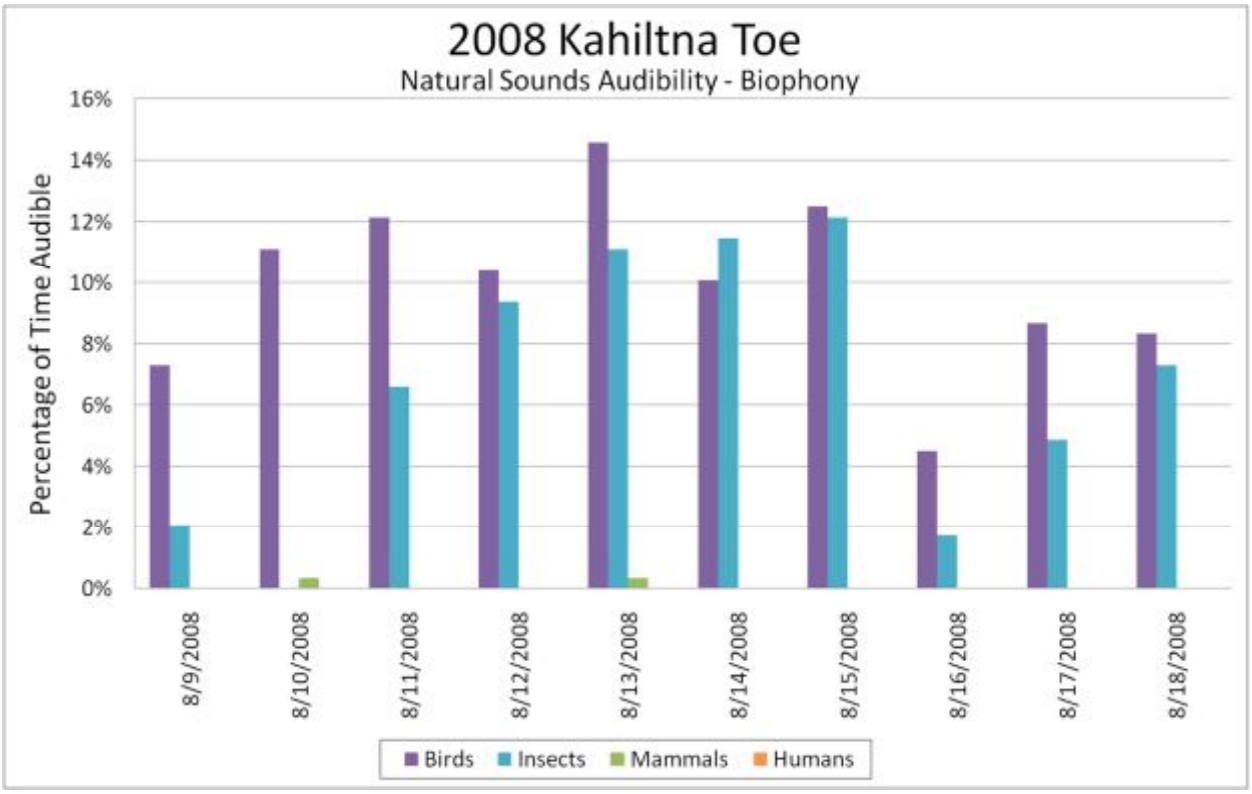


Figure 13. Percentage of time audible for biophonic sounds at Toe of the Kahiltna Glacier.

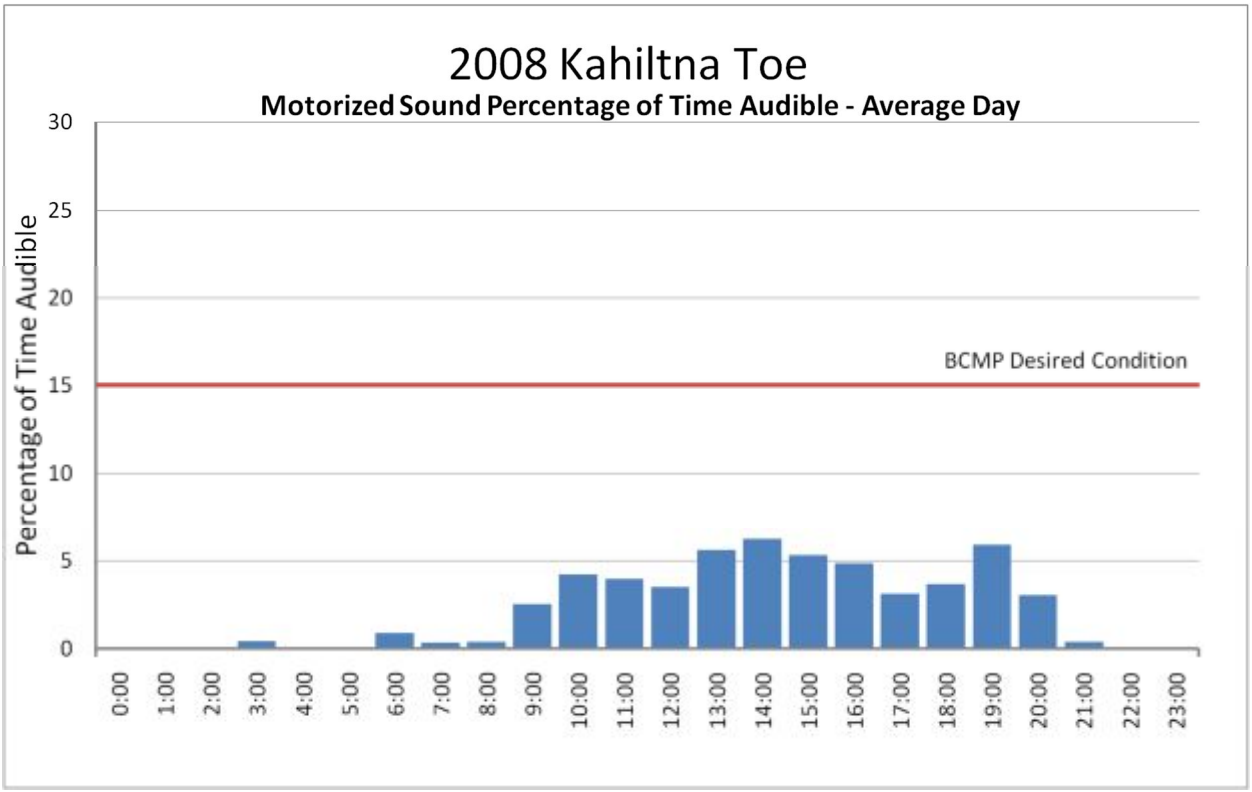


Figure 14. Audibility of mechanized noise for an average day, by hour, at Toe of the Kahiltna Glacier.

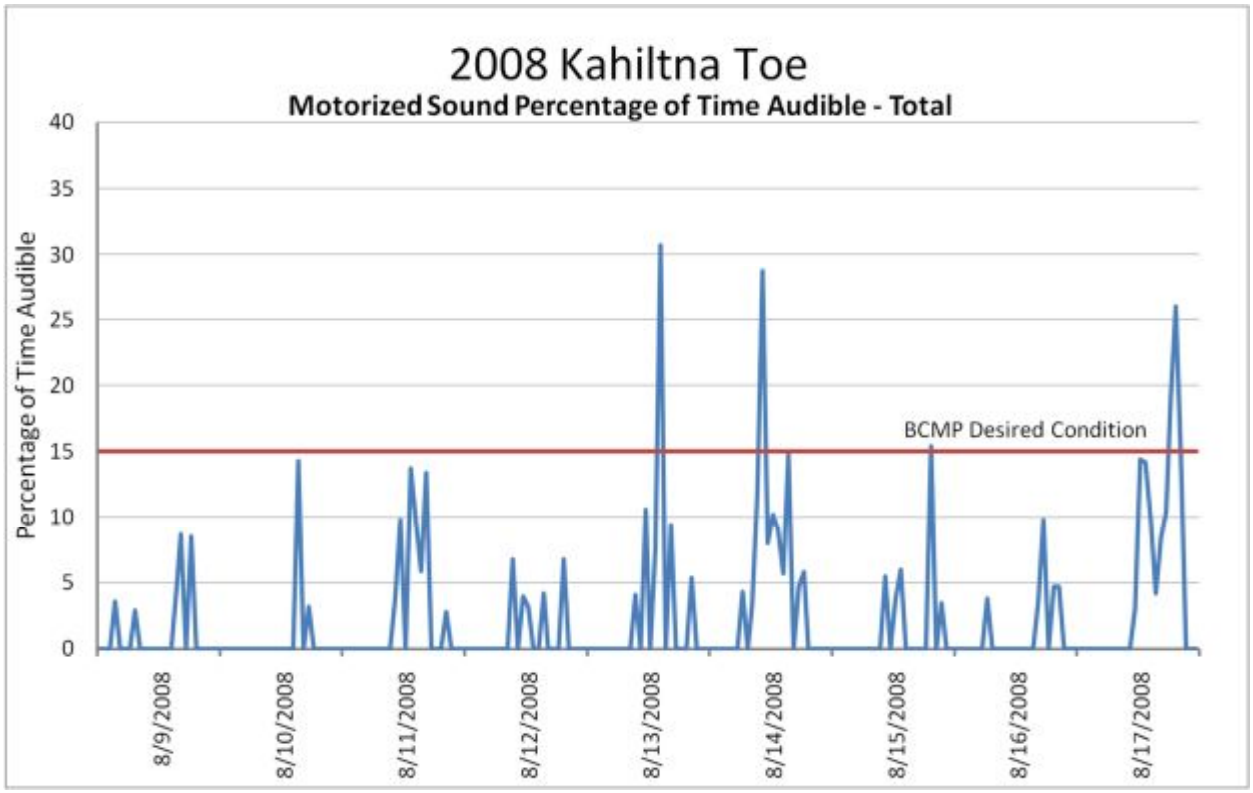


Figure 15. Audibility of mechanized noise at Toe of the Kahiltna Glacier.

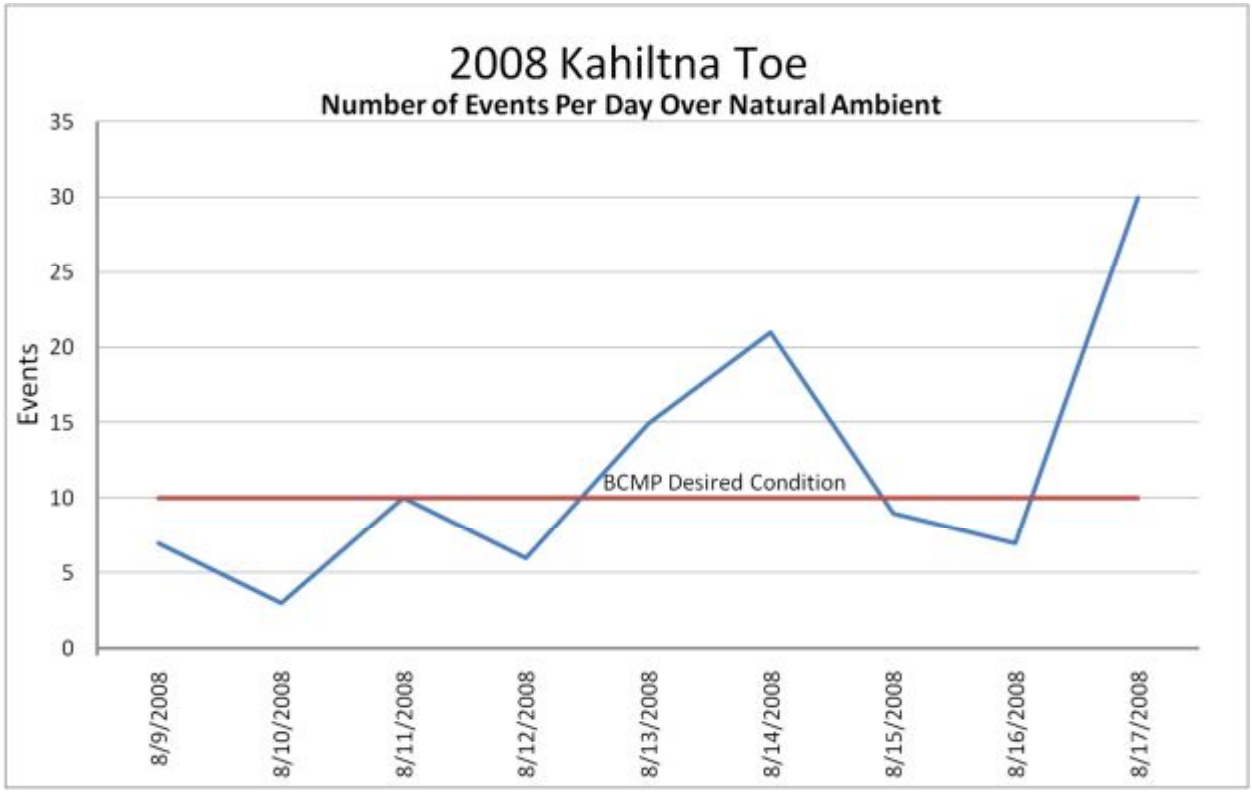


Figure 16. Number of mechanized noise events identified per day at Toe of the Kahiltna Glacier.

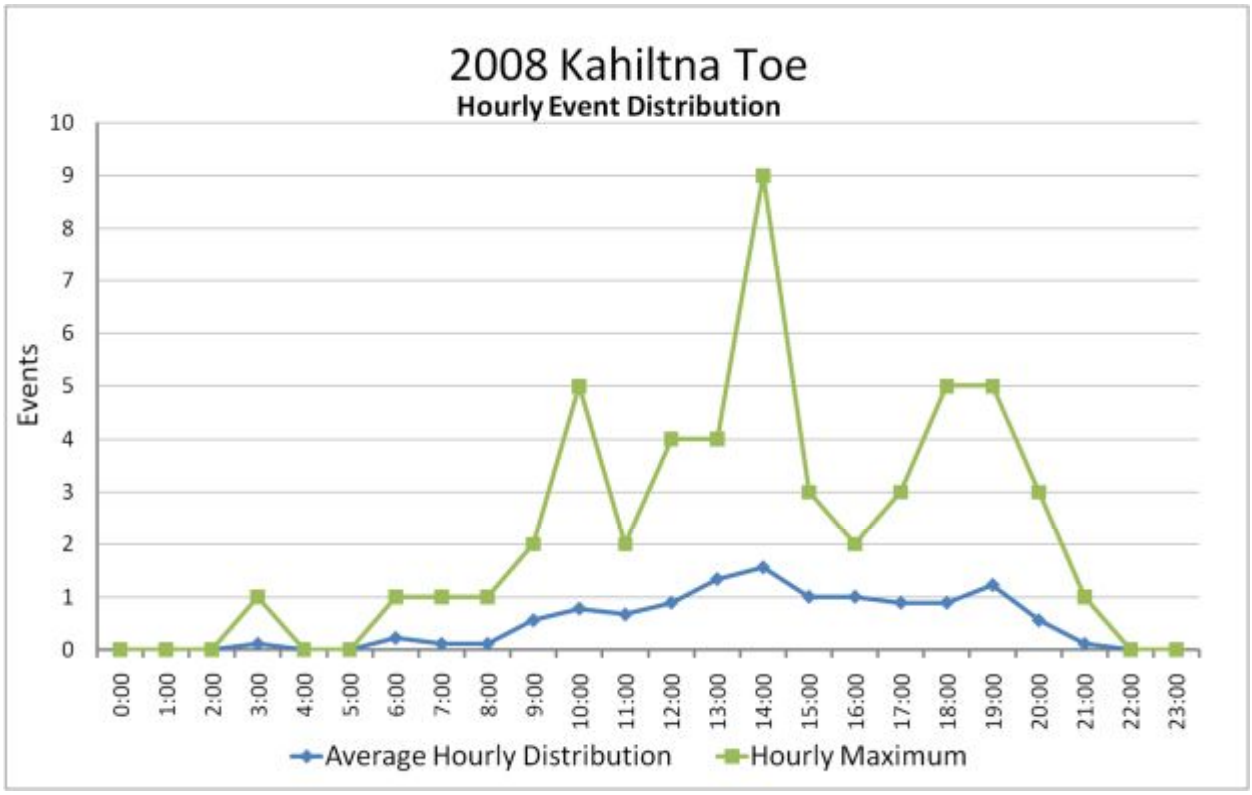


Figure 17. Hourly average and maximum mechanized event distribution at Toe of the Kahiltna Glacier.

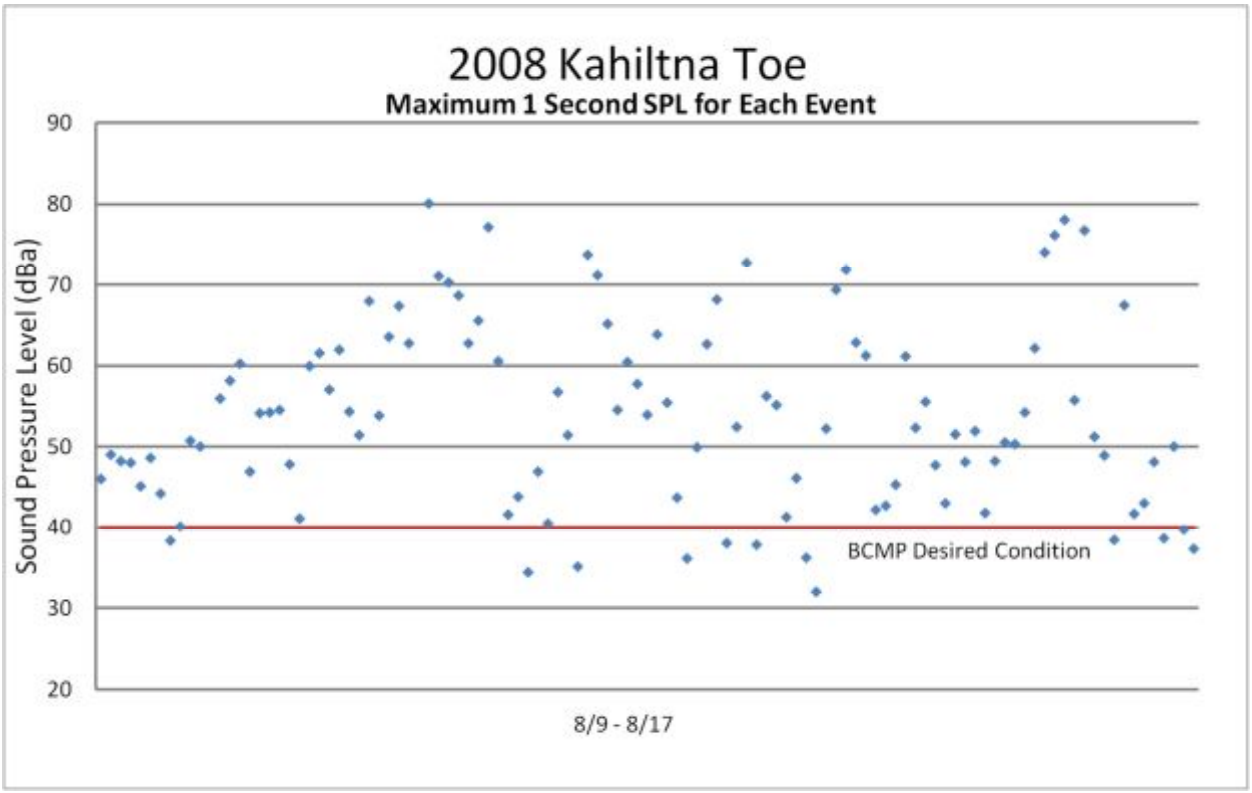
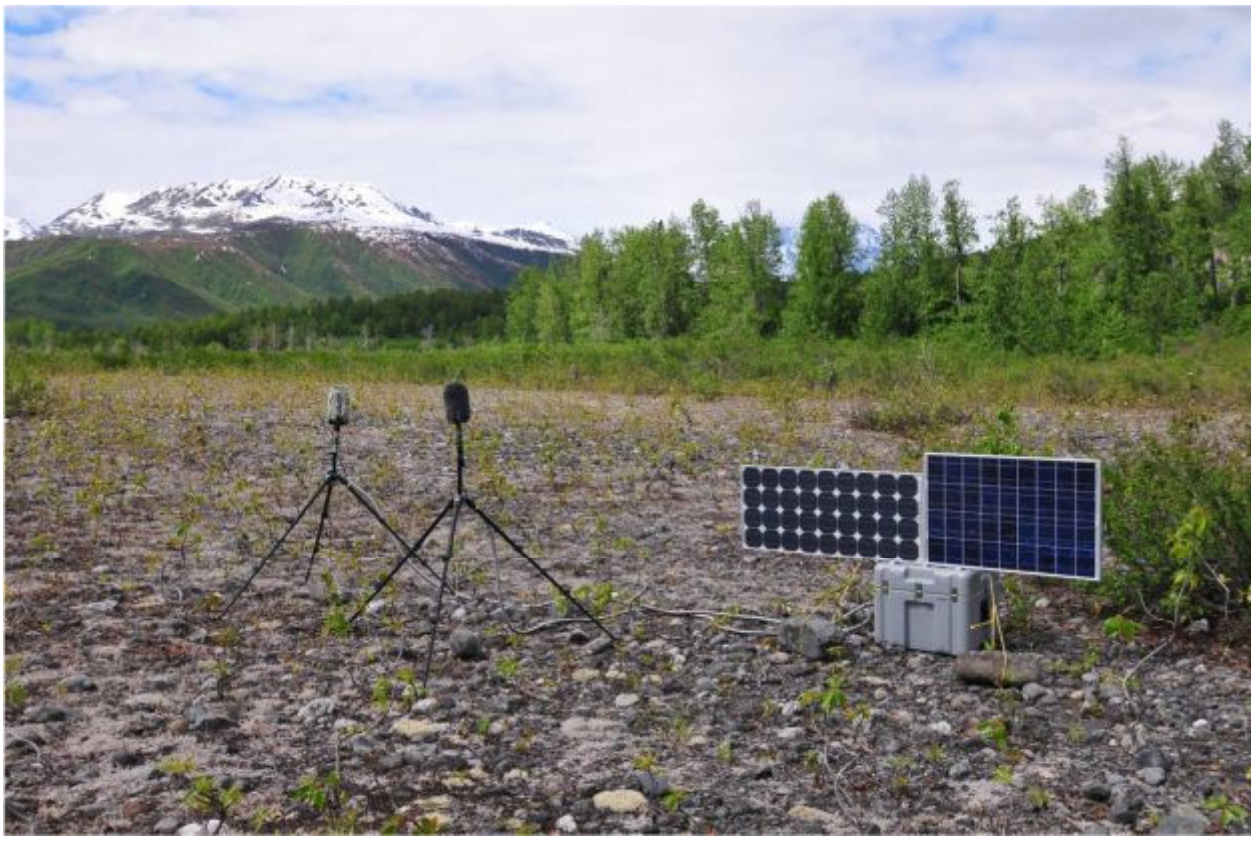


Figure 18. Maximum 1 second SPL for each mechanized event identified at Toe of the Kahiltna Glacier.

Toe of the Tokositna Glacier



Location Description: Located on the gravel bar at the Toe of the Tokositna Glacier.

Purpose/Project: Location chosen at the request of park managers to monitor the level of scenic and airtaxi traffic operating over the Tokositna Glacier.

Coordinates: Lat. 62.66451, Long. 150.79065 Elevation: 273 Meters

Time at Location: 3-July-2008 – 13-September-2008

BCMP Management Zone: Very High

Park Ecoregion: Lowland Floodplains & Terraces & Fans

Access: Helicopter

Summary: The purpose of the toe of the Tokositna Glacier location was to collect data in this common scenic flight and airtaxi corridor. This site had also been sampled in 2005 and 2001, and is one of the only sites in the park that has previous data from which to gather indications of trend.

The most commonly heard sounds at this site were running water (audible 100% of the time), birds (19%), rain (15%), and wind (6%). Mechanized sound was audible 5.08% of the time on average. Conditions exceeded the BCMP percent audible standard 0% of the time, number of events per day 6% of the time, and maximum SPL 17% of the time.

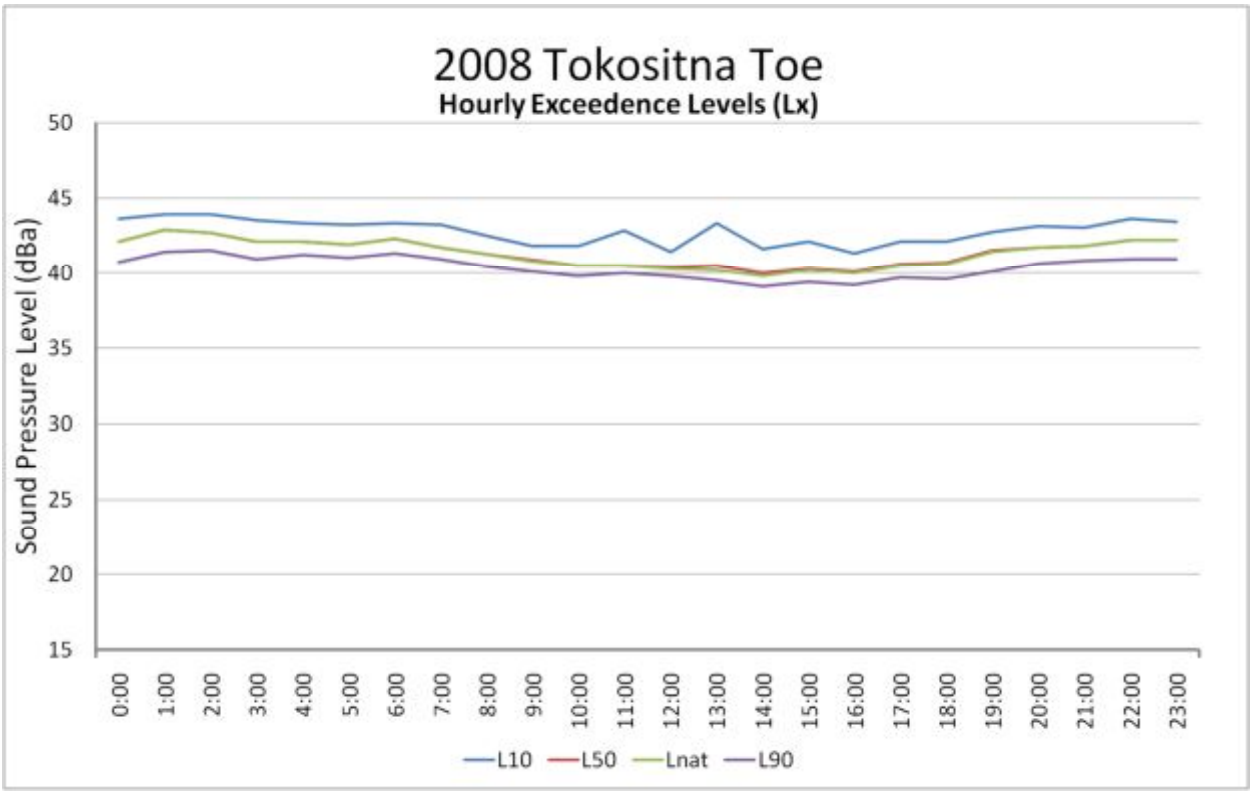


Figure 19. Exceedence levels for Toe of the Tokositna Glacier.

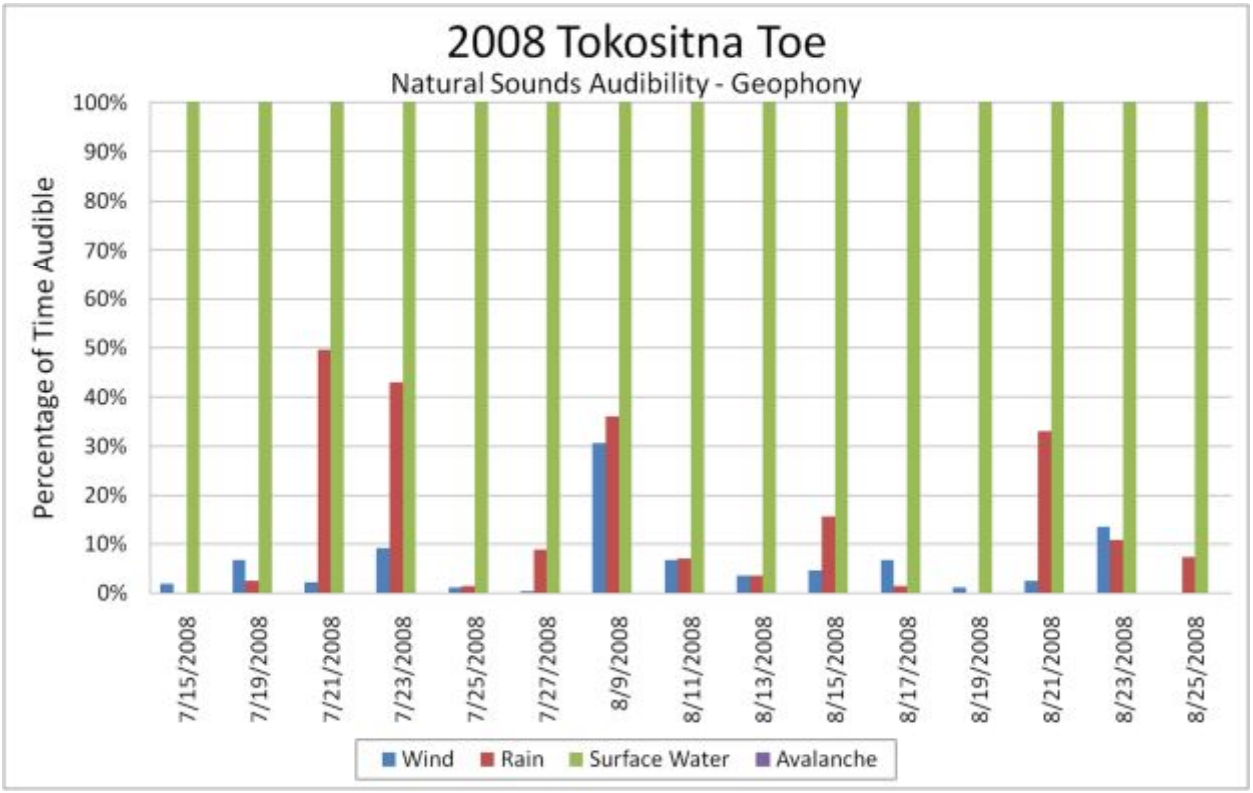


Figure 20. Percentage of time audible for geophonic sounds at Toe of the Tokositna Glacier.

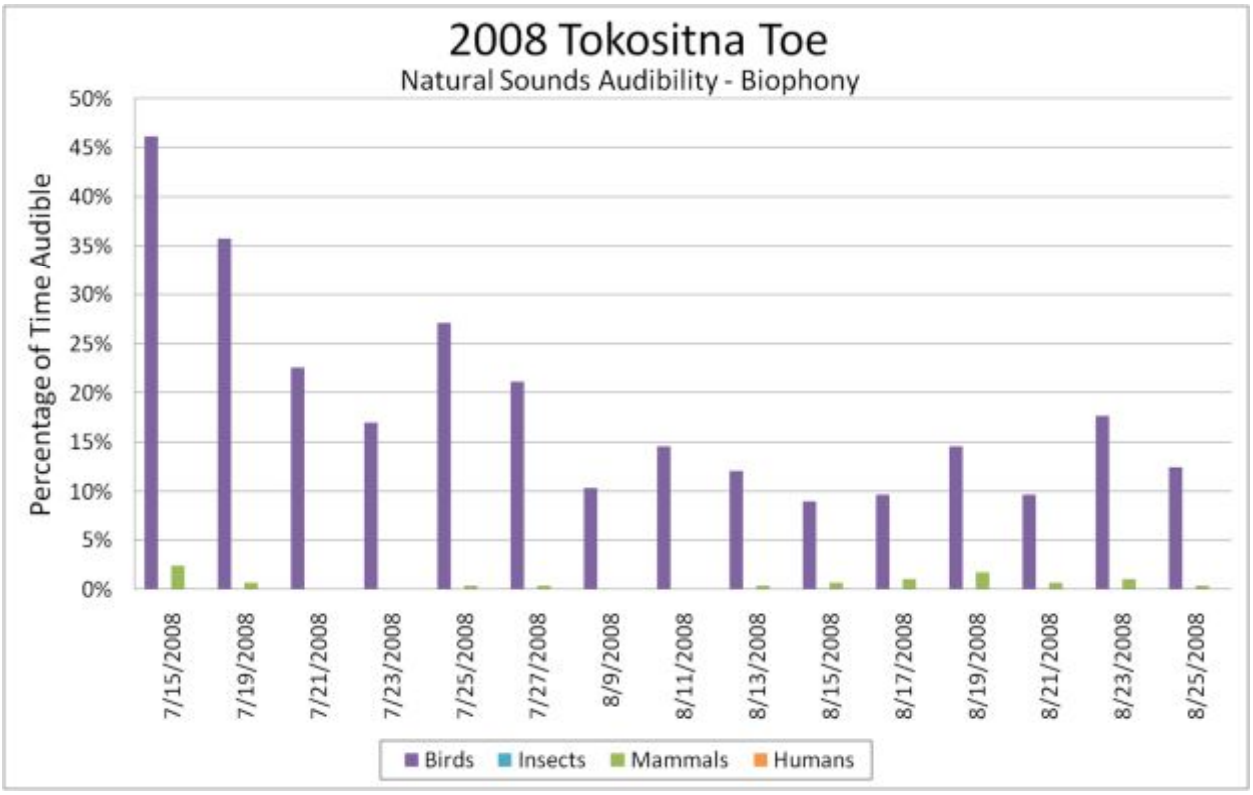


Figure 21. Percentage of time audible for biophonic sounds at Toe of the Tokositna Glacier.

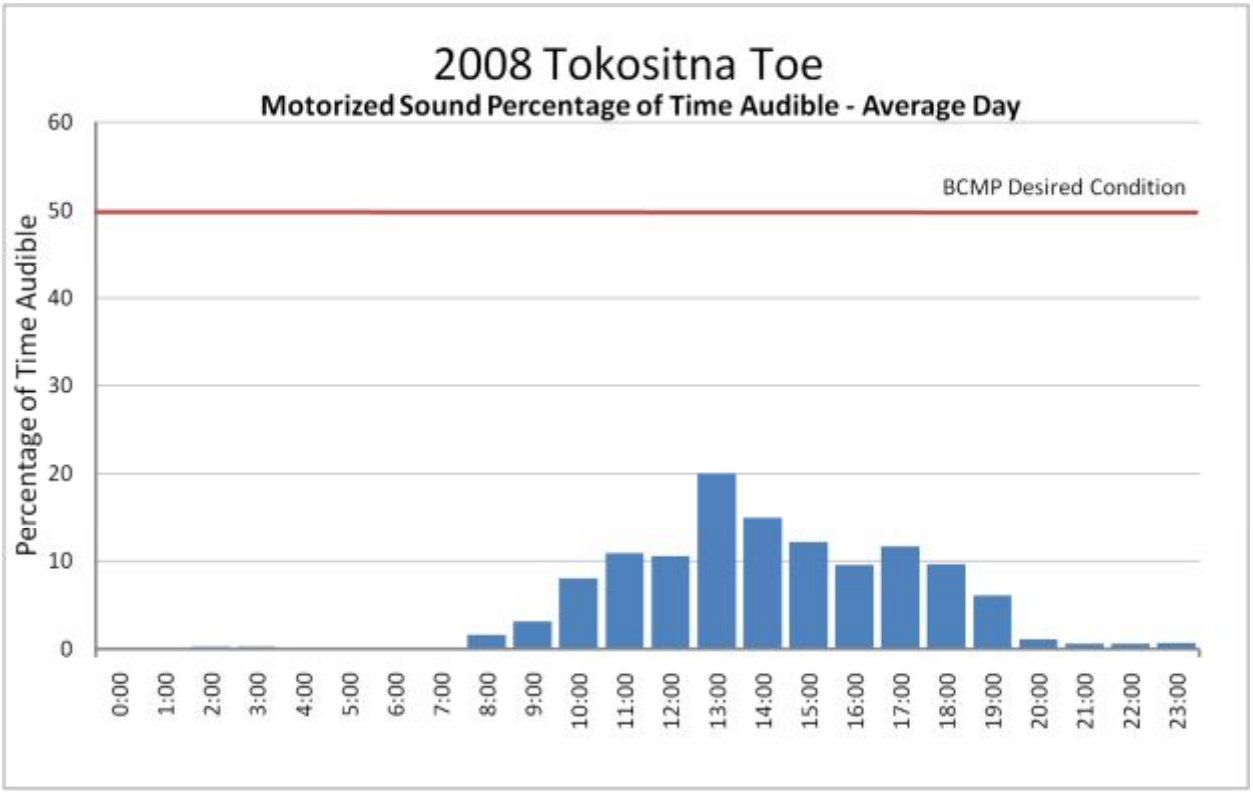


Figure 22. Audibility of mechanized noise for an average day, by hour, at Toe of the Tokositna Glacier.

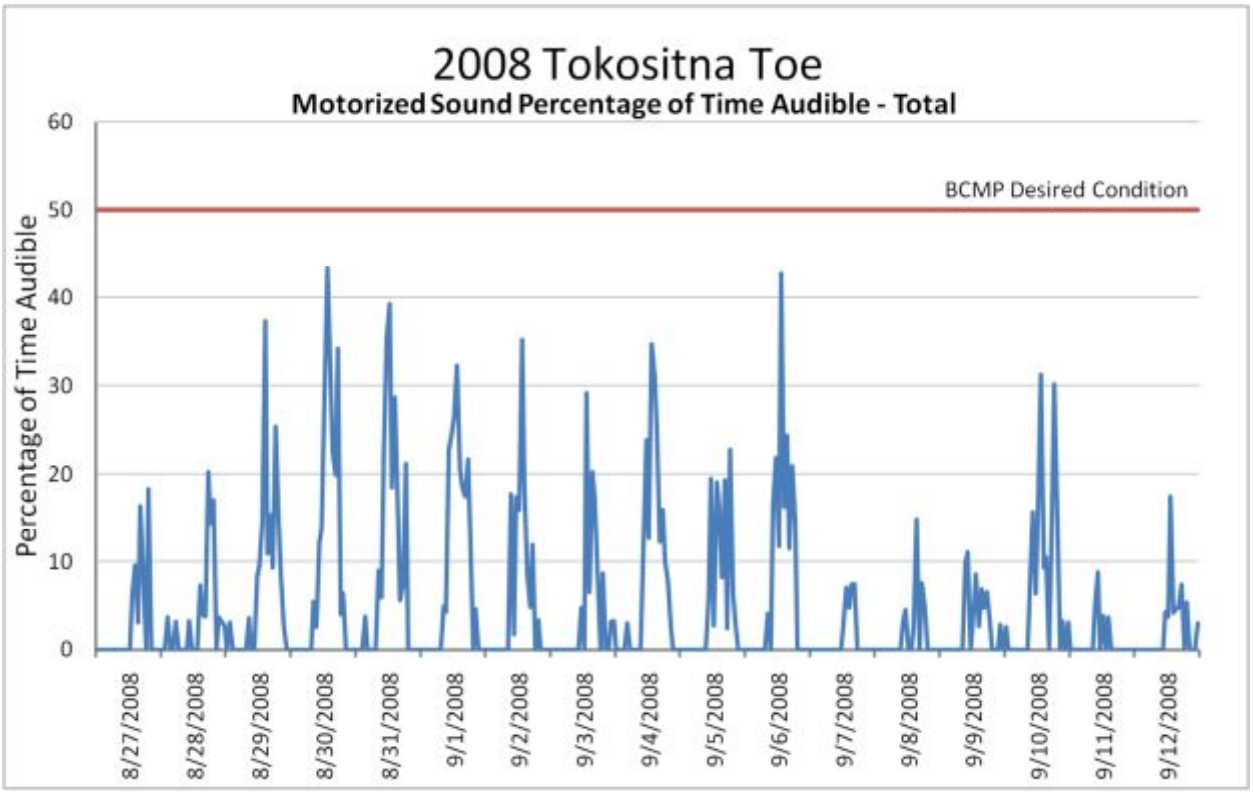


Figure 23. Audibility of mechanized noise at Toe of the Tokositna Glacier

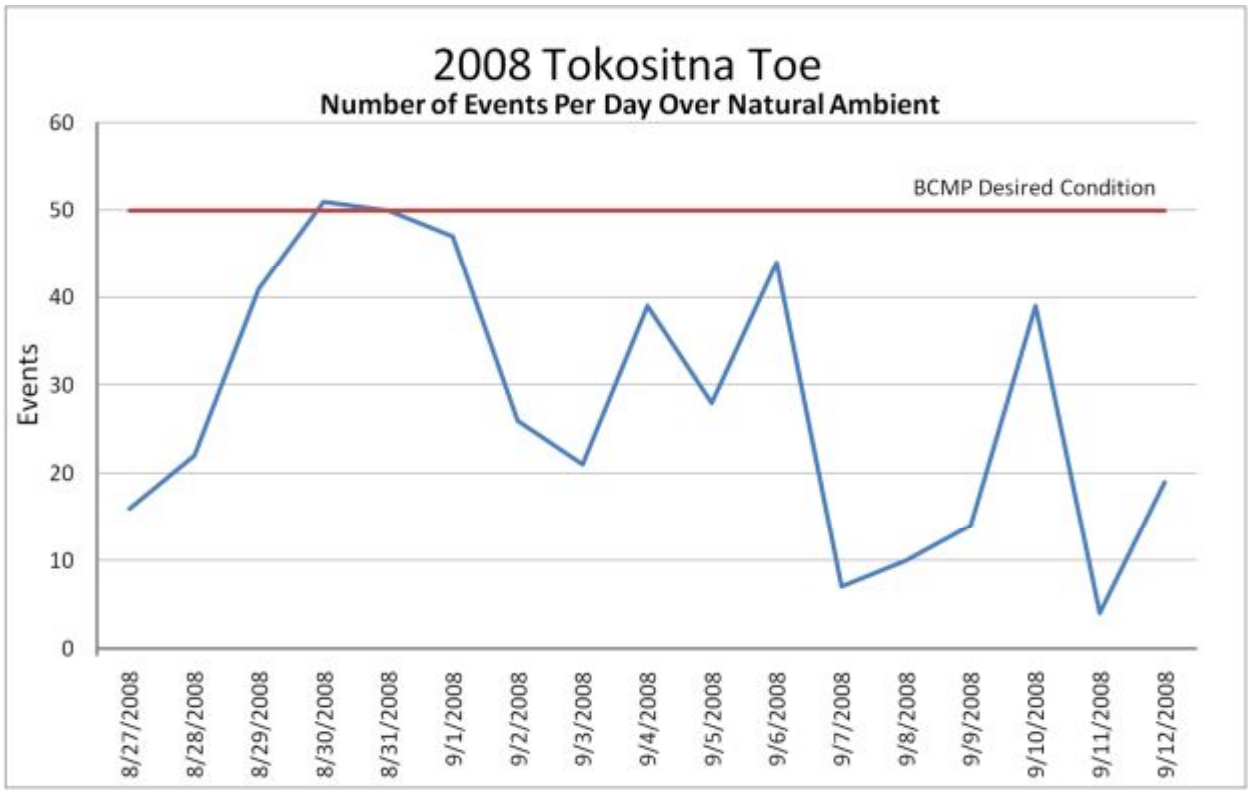


Figure 24. Number of mechanized noise events identified per day at Toe of the Tokositna Glacier.

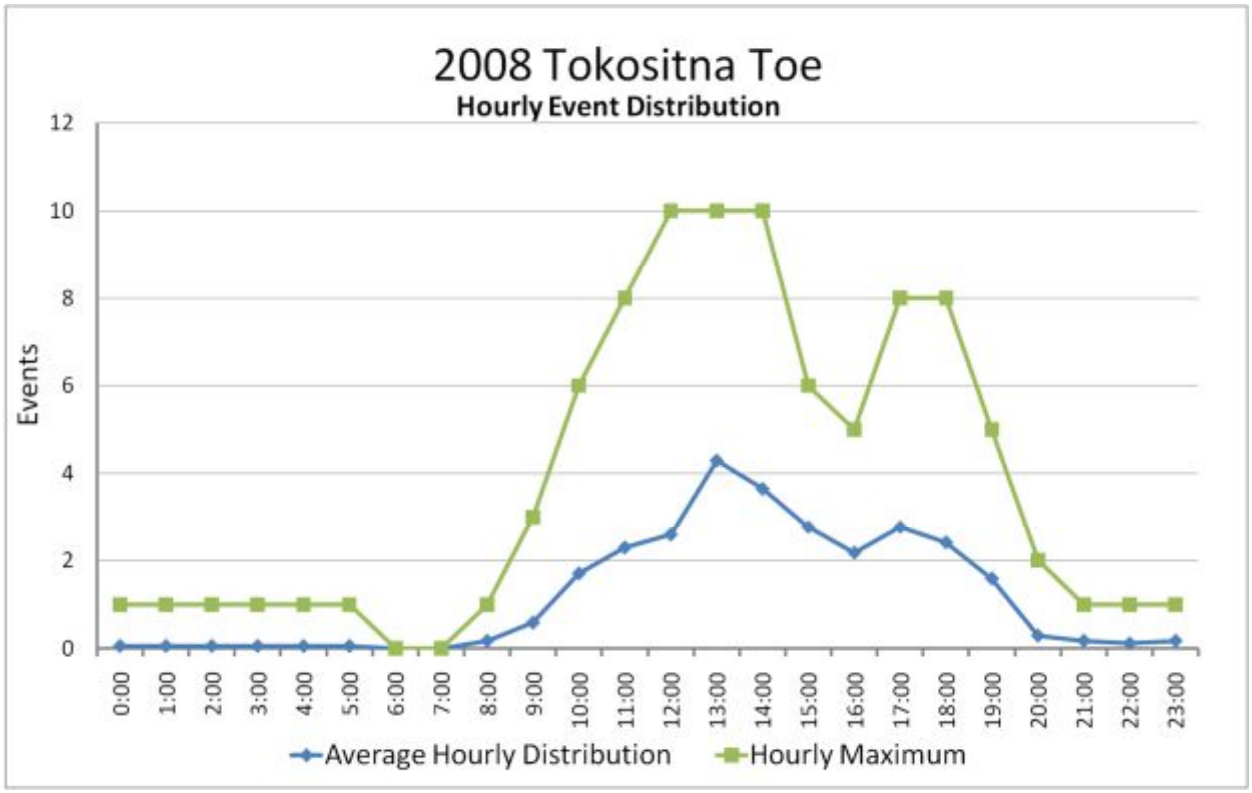


Figure 25. Hourly average and maximum mechanized event distribution at Toe of the Tokositna Glacier.

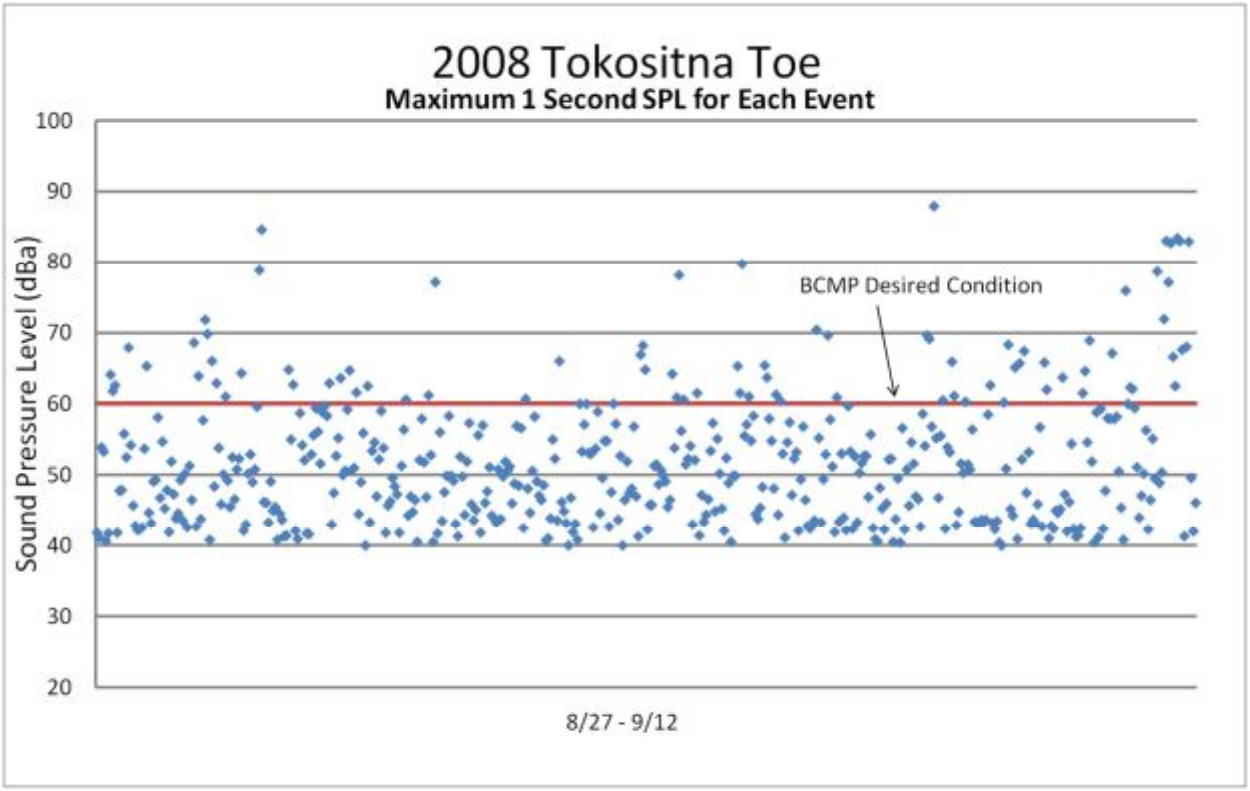


Figure 26. Maximum 1 second SPL for each mechanized event identified at Toe of the Tokositna Glacier.

Upper Wigand Creek

Location Description: Located ~500ft west of Wigand Creek, ~4.5Km South of the Park Boundary.

Purpose/Project: Location randomly chosen from the LTEM grid as part of the long-term Denali Soundscape inventorying and monitoring plan.

Coordinates: Lat. 63.76028, Long. 149.98921 Elevation: 639 Meters

Time at Location: 31-May-2008 – 18-September-2008

BCMP Management Zone: Low Park Ecoregion: Toklat Basin Lowlands

Access: Helicopter

Summary: The purpose of the Upper Wigand Creek location was to collect data at one of the long-term ecological monitoring (LTEM) grid points, as outlined in the above sampling plan. LTEM grid point #217 was stratified as an Old Park (designated Wilderness) location and randomly selected from all locations requiring aircraft access.

The most commonly heard sounds at this site were running water (audible 60% of the time), birds (28%), wind (14%), and mammals (6%). Mechanized sound was audible 2.66% of the time on average. Conditions exceeded the BCMP percent audible standard 23% of the time, number of events per day 93% of the time, and maximum SPL 40% of the time.

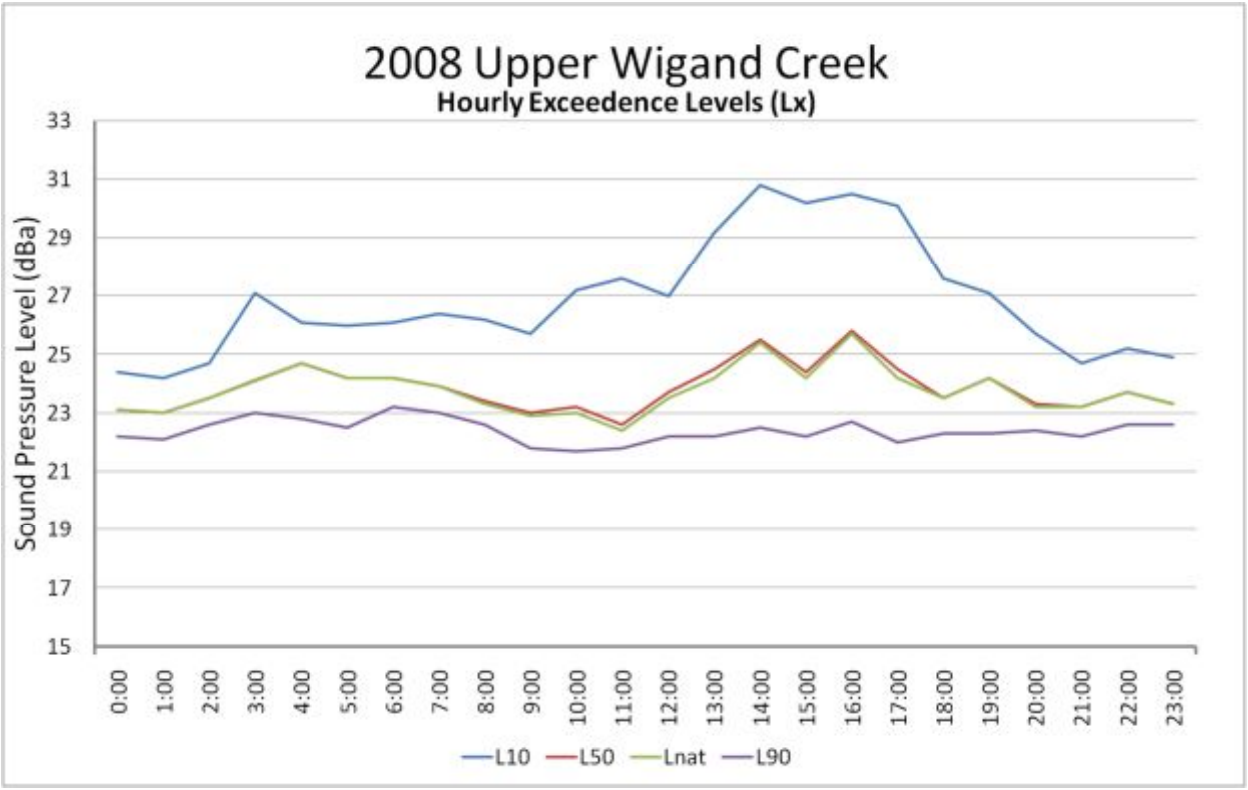


Figure 27. Exceedence levels for Upper Wigand Creek.

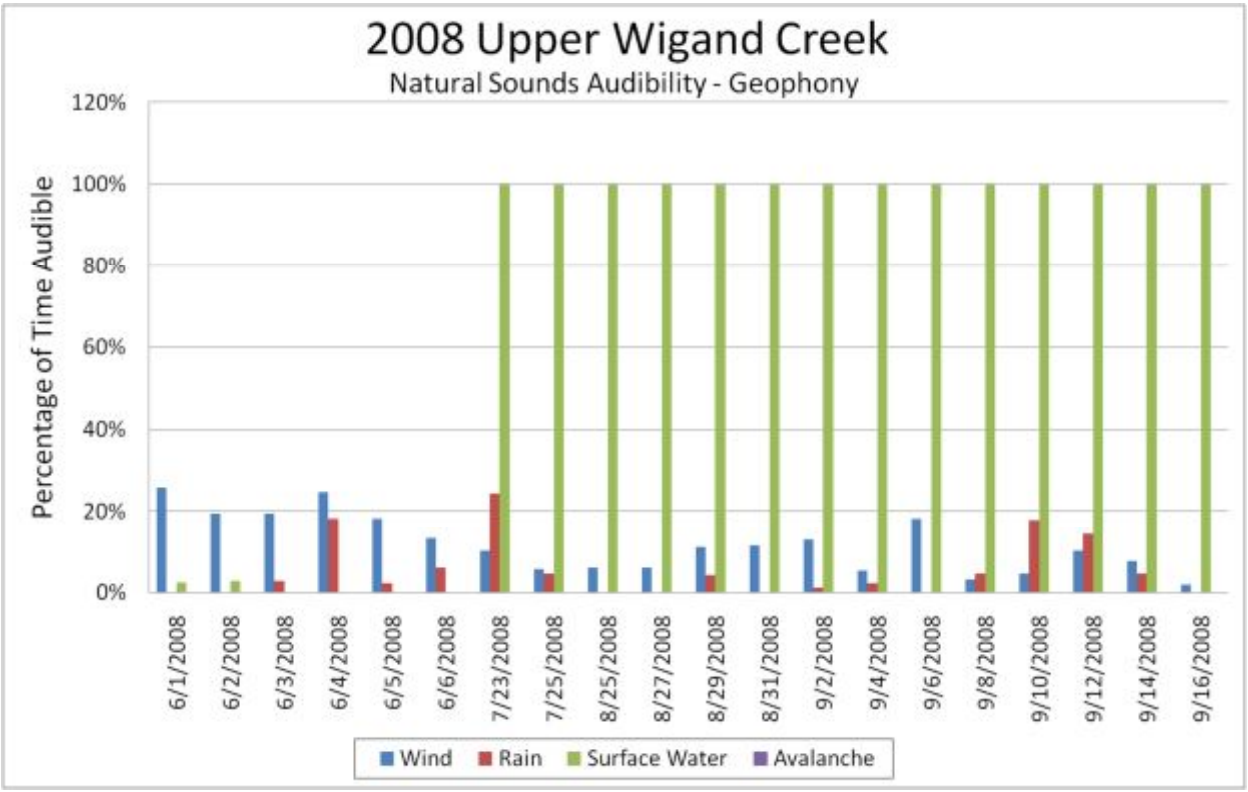


Figure 28. Percentage of time audible for geophonic sounds at Upper Wigand Creek.

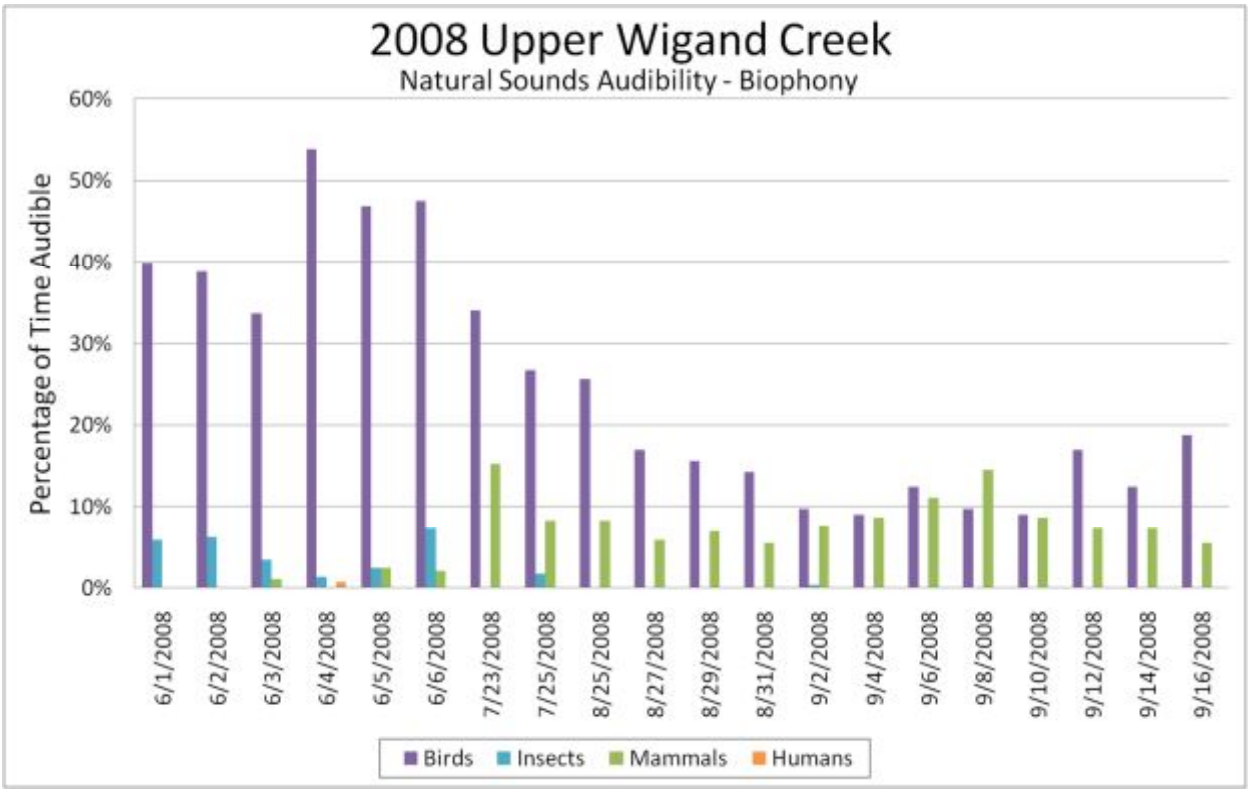


Figure 29. Percentage of time audible for biophonic sounds at Upper Wigand Creek.

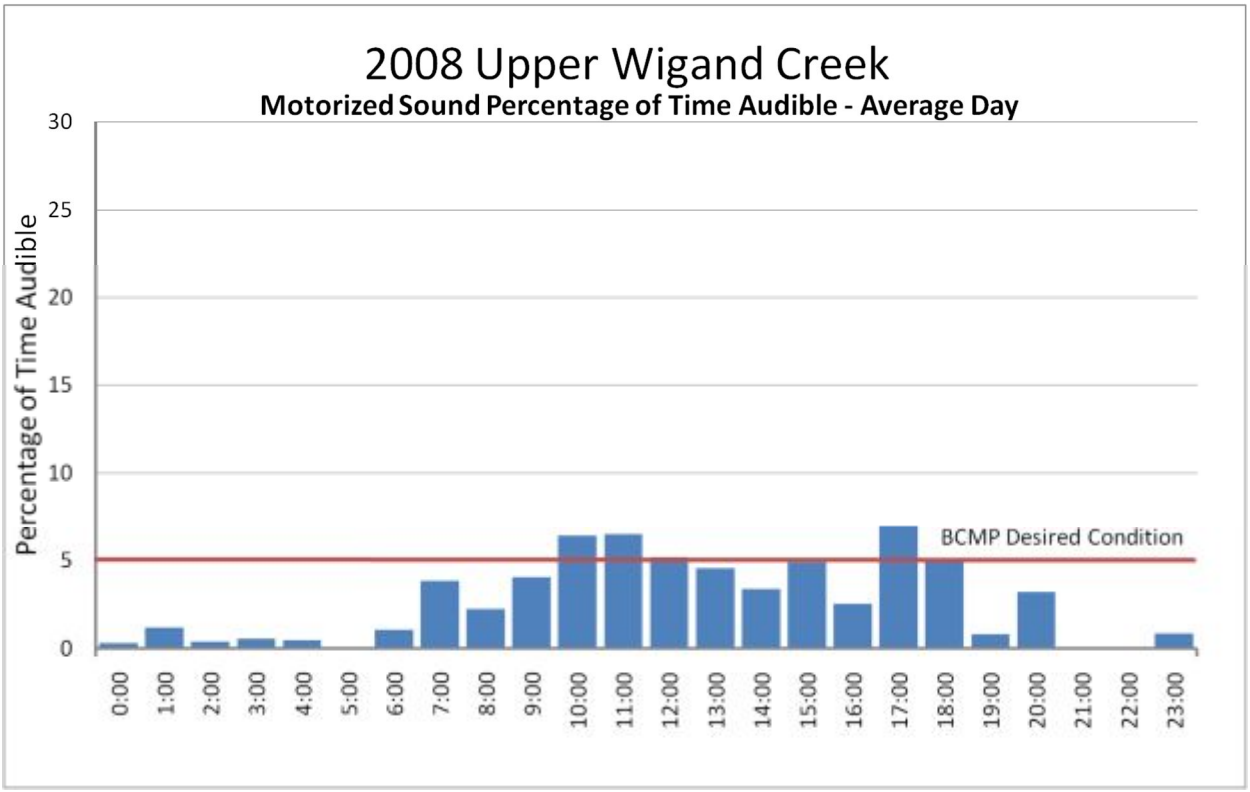


Figure 30. Audibility of mechanized noise for an average day, by hour, at Upper Wigand Creek.

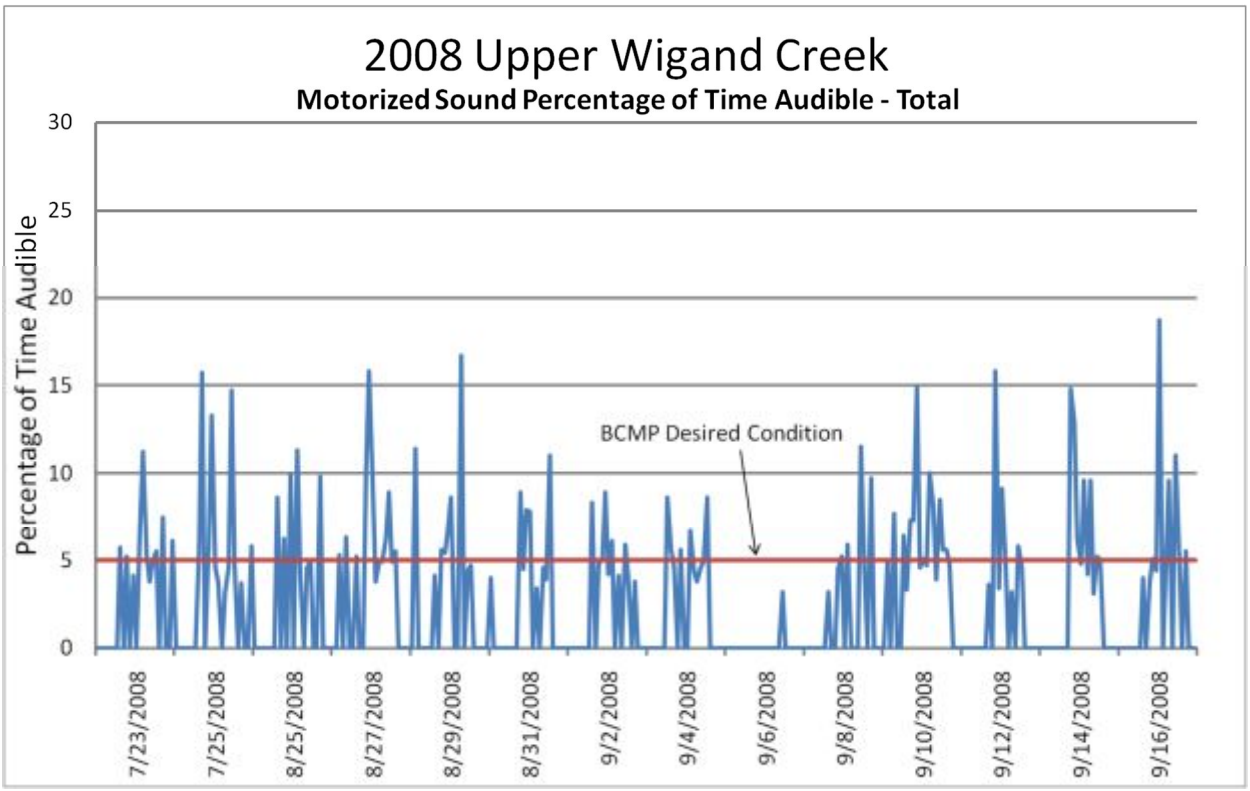


Figure 31. Audibility of mechanized noise at Upper Wigand Creek.

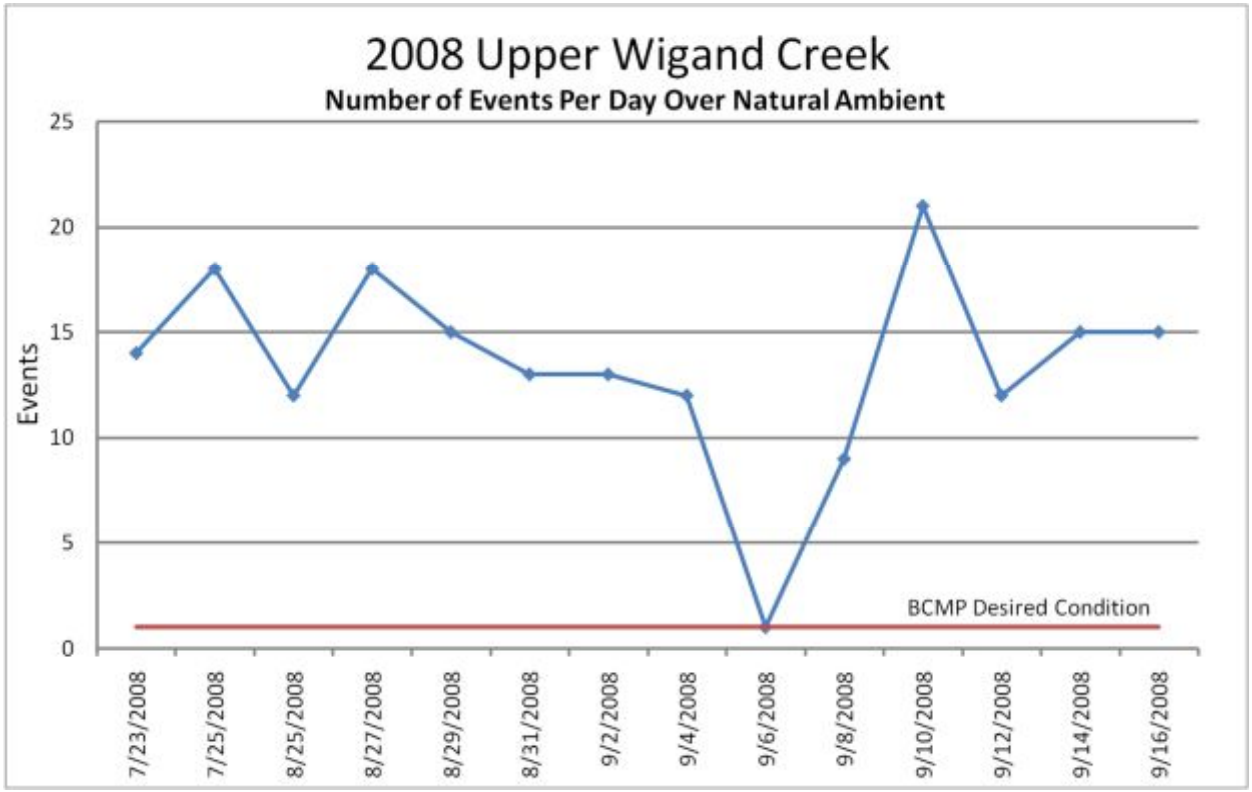


Figure 32. Number of mechanized noise events identified per day at Upper Wignad Creek.

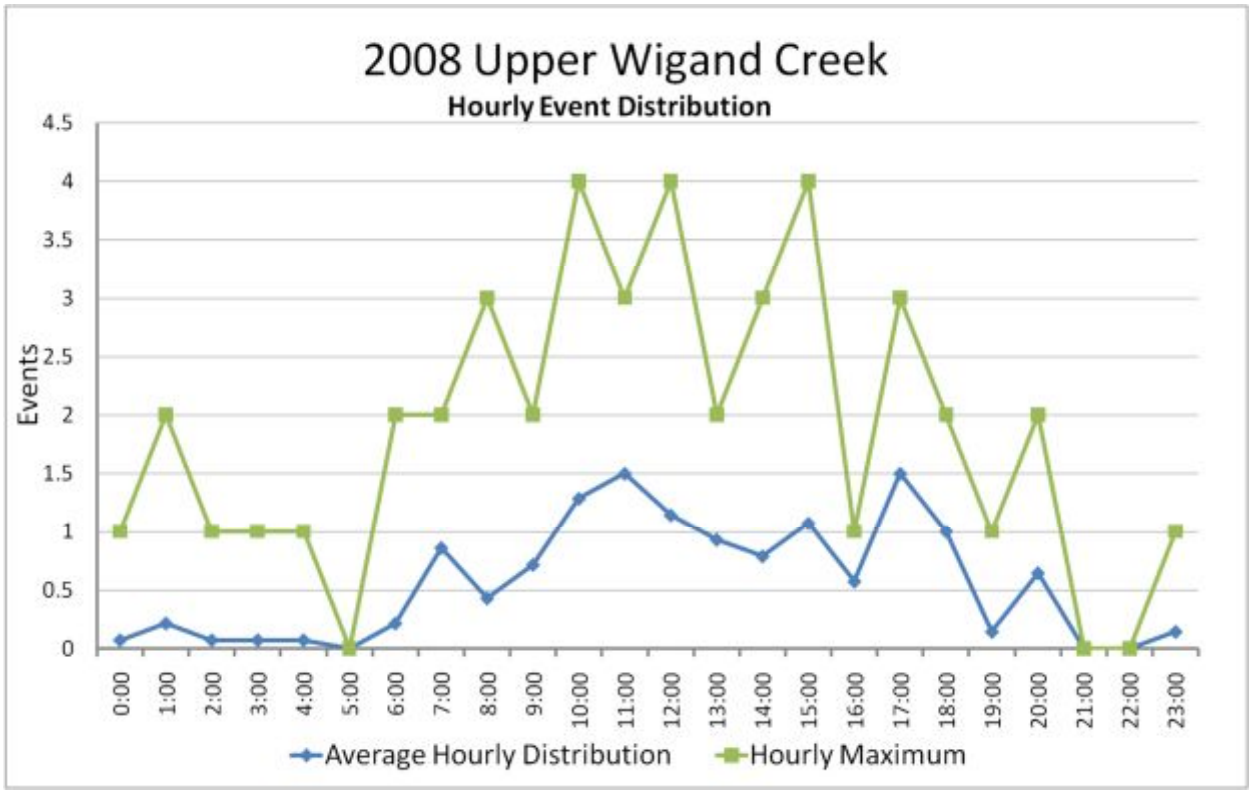


Figure 33. Hourly average and maximum mechanized event distribution at Upper Wigand Creek.

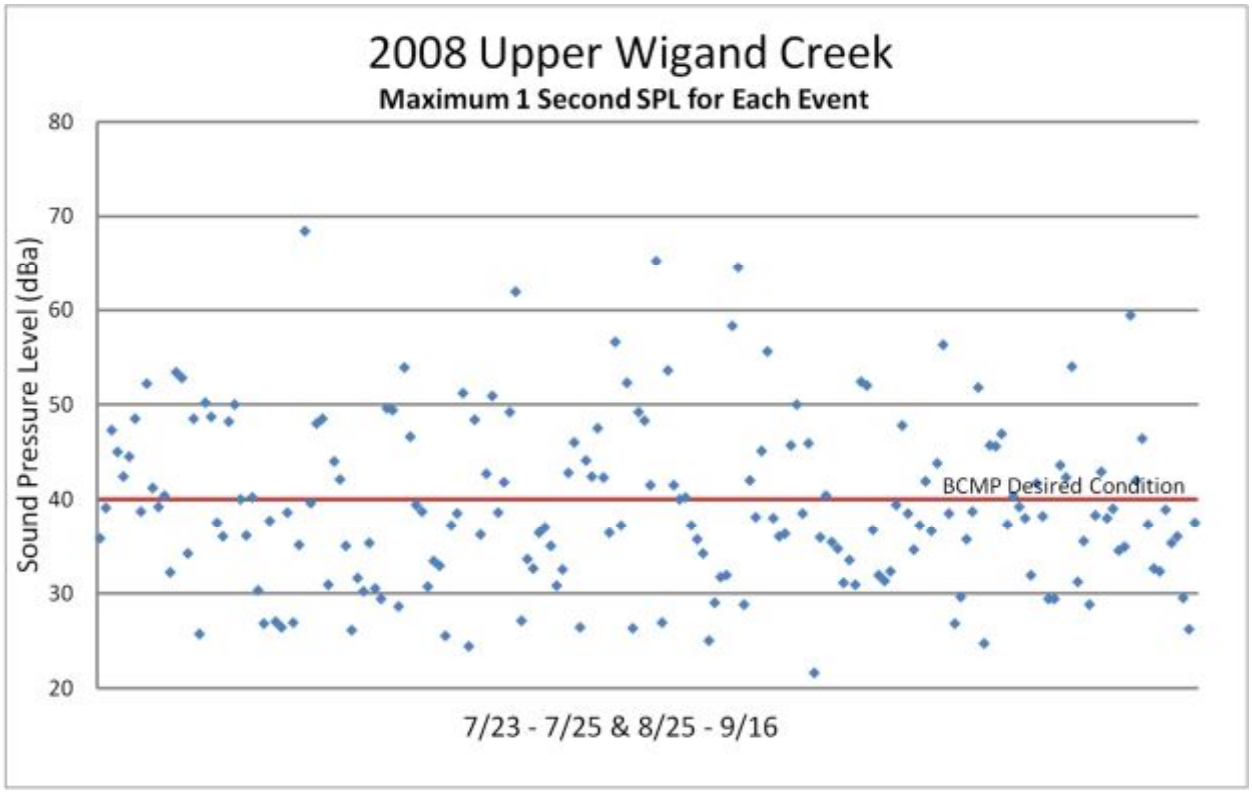


Figure 34. Maximum 1 second SPL for each mechanized event identified at Upper Wigand Creek.

Upper Slippery Creek

Location Description: ~1 km west of Upper Slippery Creek.

Purpose/Project: Location randomly chosen from the LTEM grid as part of the long-term Denali Soundscape inventorying and monitoring plan.

Coordinates: Lat. 63.25249, Long. 151.24640 Elevation: 883 Meters

Time at Location: 23-July-2008 – 11-August-2008

BCMP Management Zone: Low Park Ecoregion: Glaciated Uplands

Access: Helicopter

Summary: The purpose of the Upper Slippery Creek location was to collect data at one of the long-term ecological monitoring (LTEM) grid points, as outlined in the above sampling plan. LTEM grid point #109 was stratified as an Old Park (designated Wilderness) location and randomly selected from all locations requiring aircraft access.

The most commonly heard sounds at this site were wind (audible 38% of the time), rain (21%), birds (7%), and mammals (7%). Mechanized sound was audible 3.89% of the time on average. Conditions exceeded the BCMP percent audible standard 24% of the time, number of events per day 100% of the time, and maximum SPL 28% of the time.

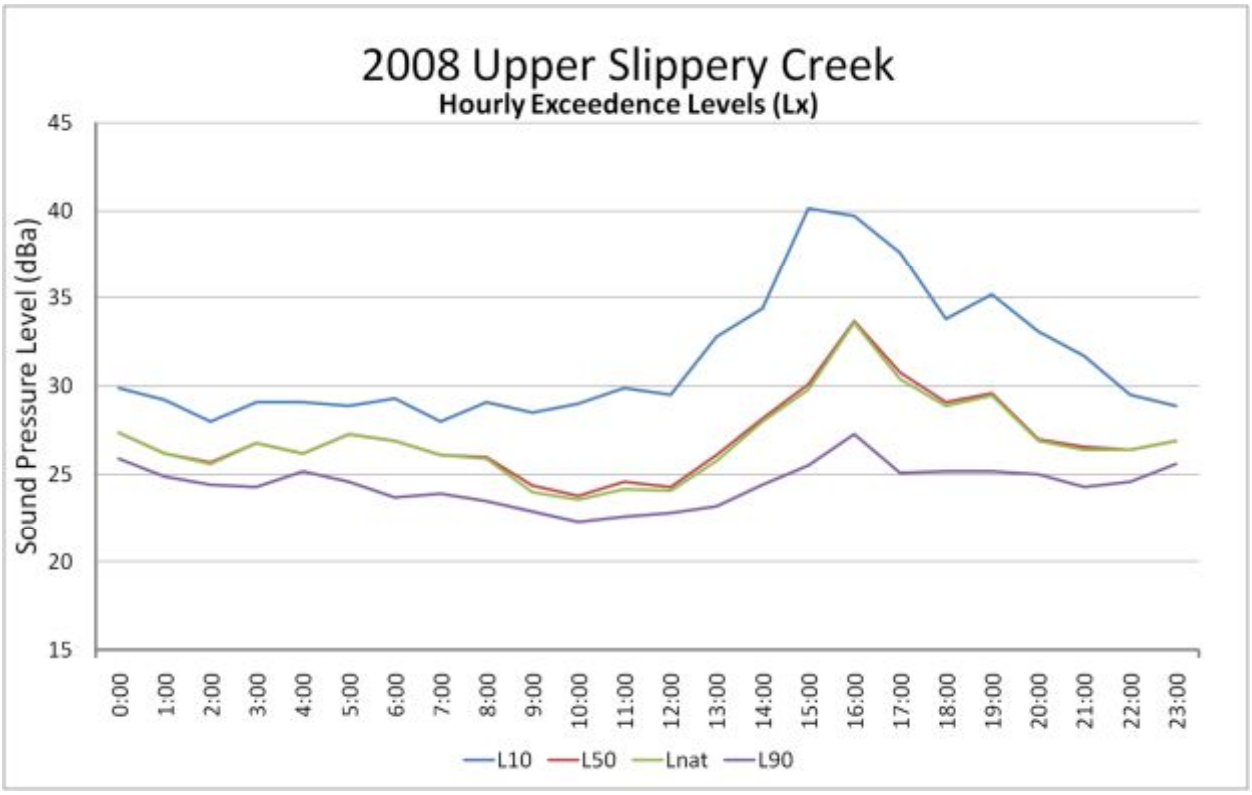


Figure 35. Exceedence levels for Upper Slippery Creek.

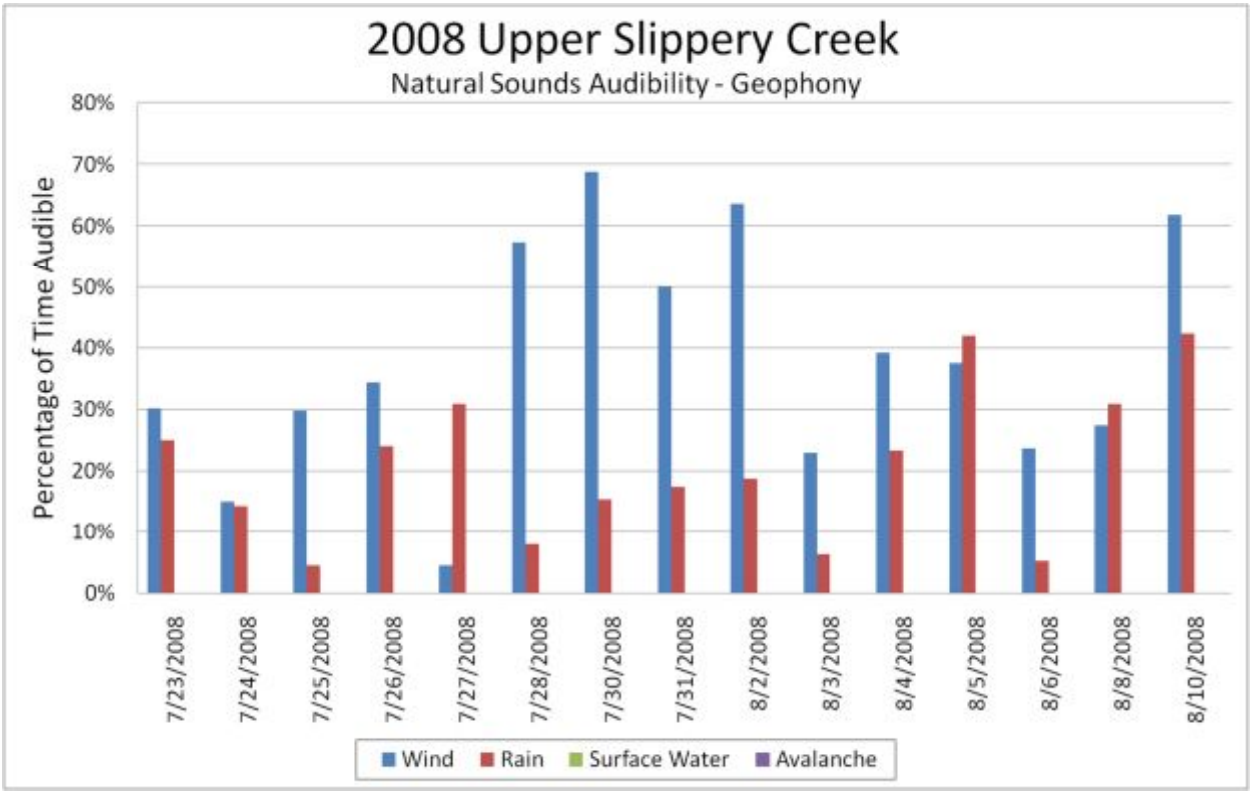


Figure 36. Percentage of time audible for geophonic sounds at Upper Slippery Creek.

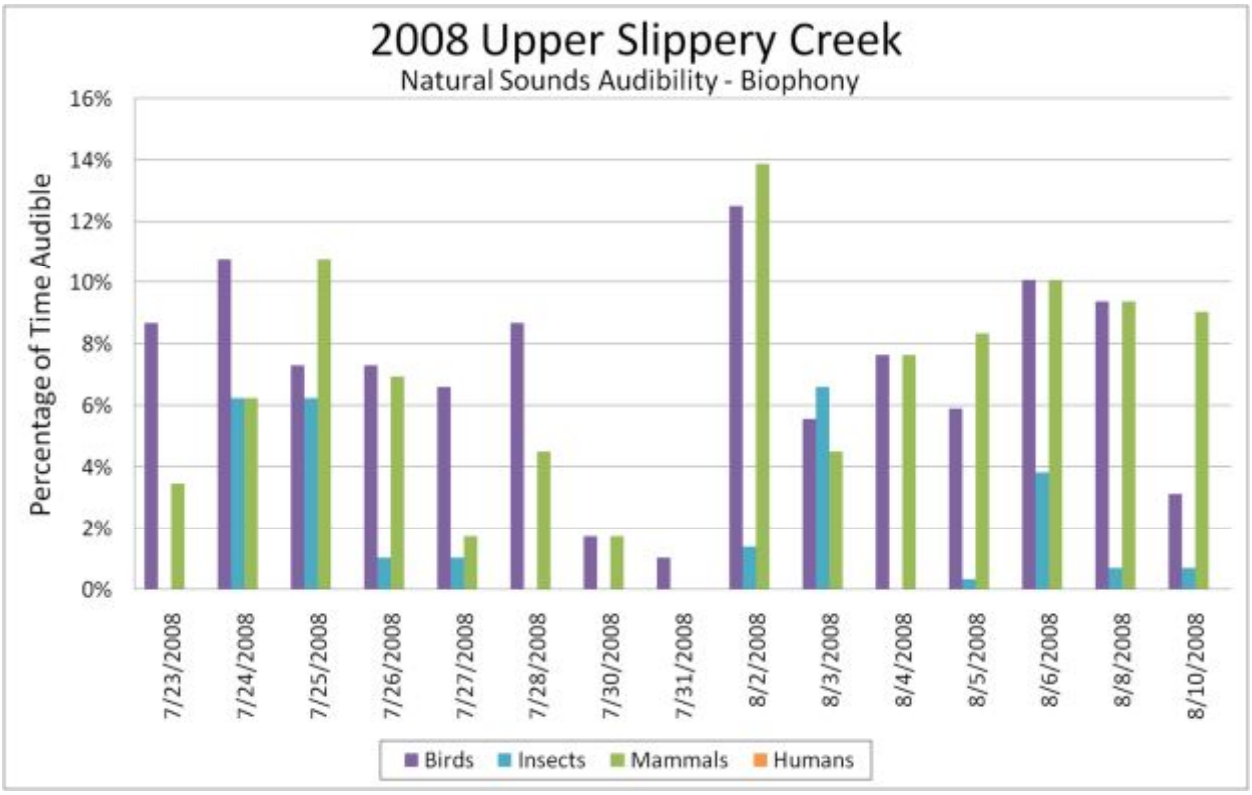


Figure 37. Percentage of time audible for biophonic sounds at Upper Slippery Creek.

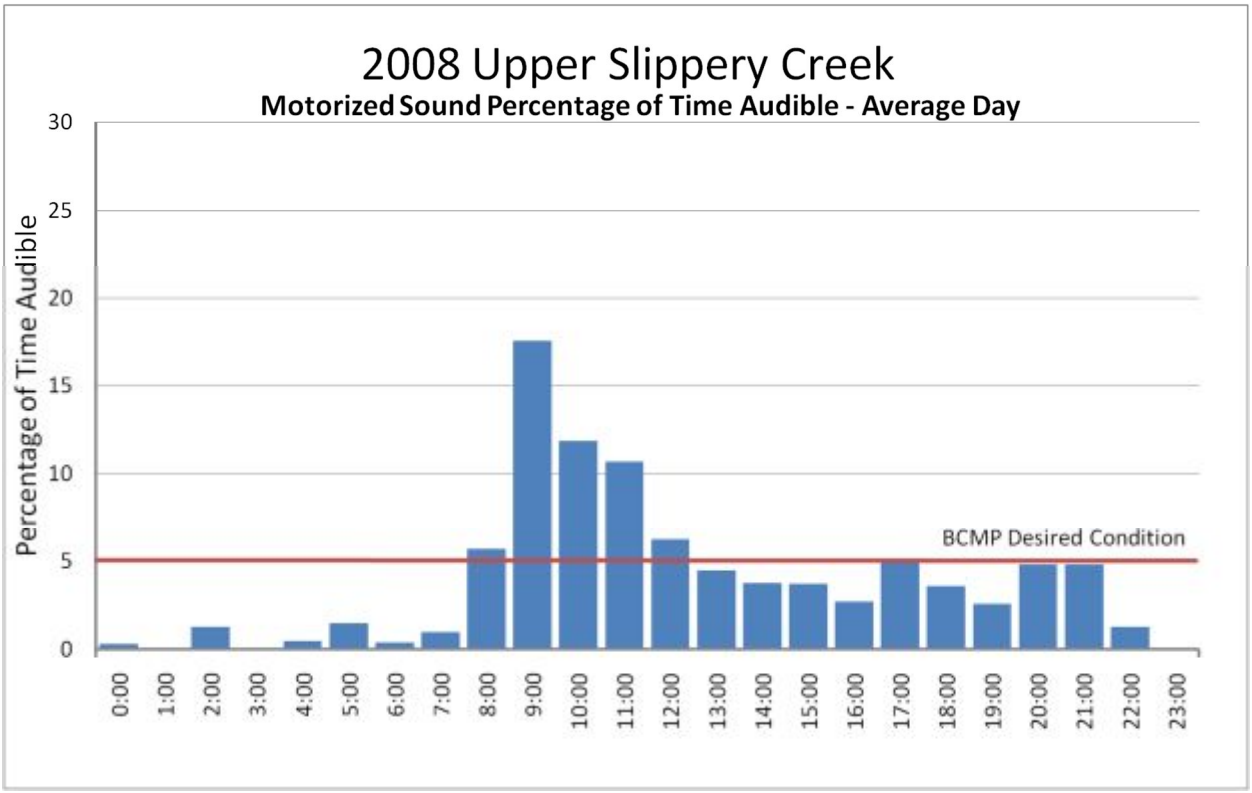


Figure 38. Audibility of mechanized noise for an average day, by hour, at Upper Slippery Creek.

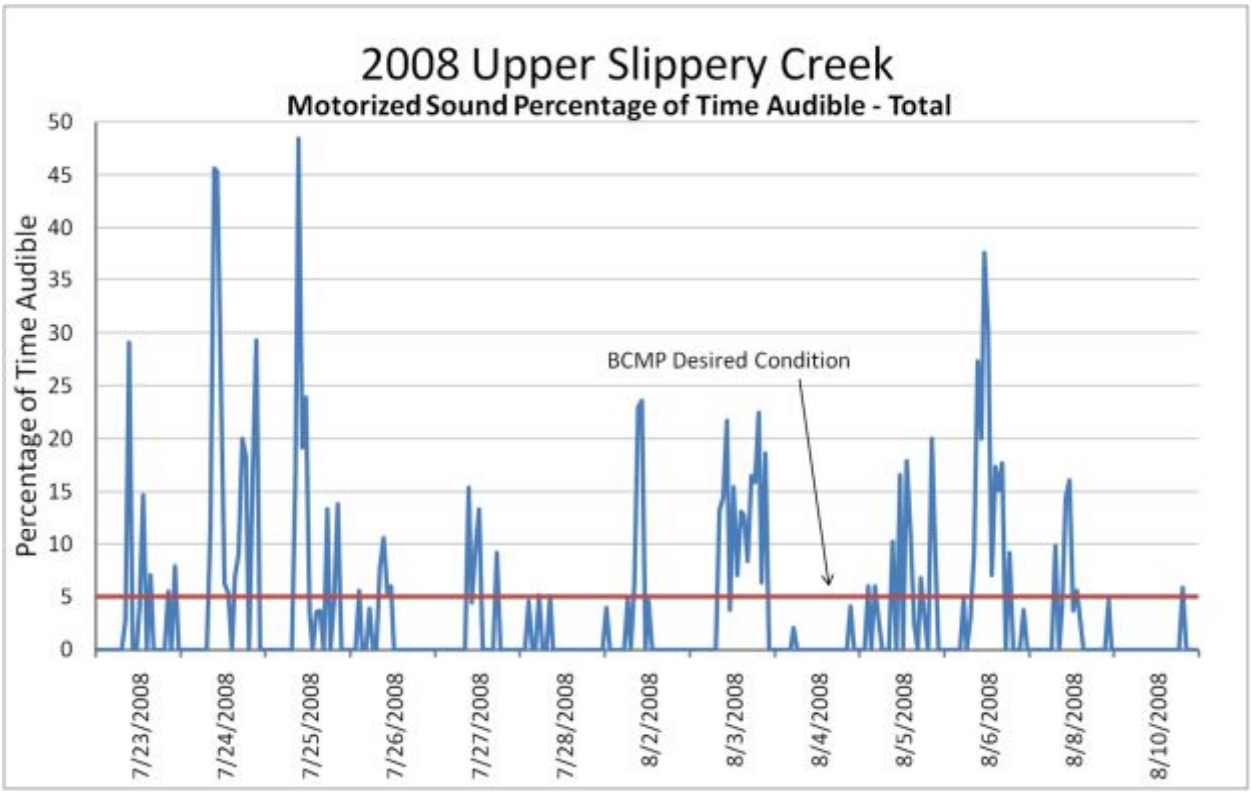


Figure 39. Audibility of mechanized noise at Upper Slippery Creek.

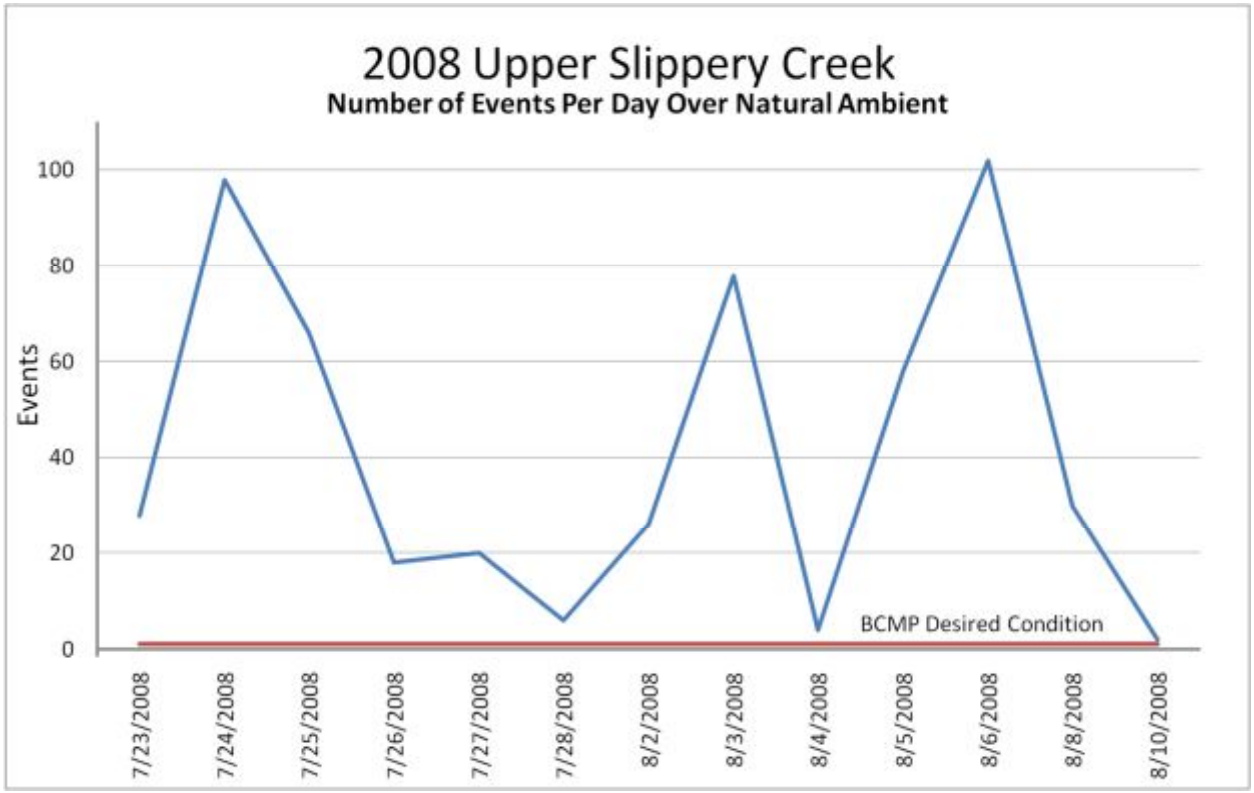


Figure 40. Number of mechanized noise events identified per day at Upper Slippery Creek.

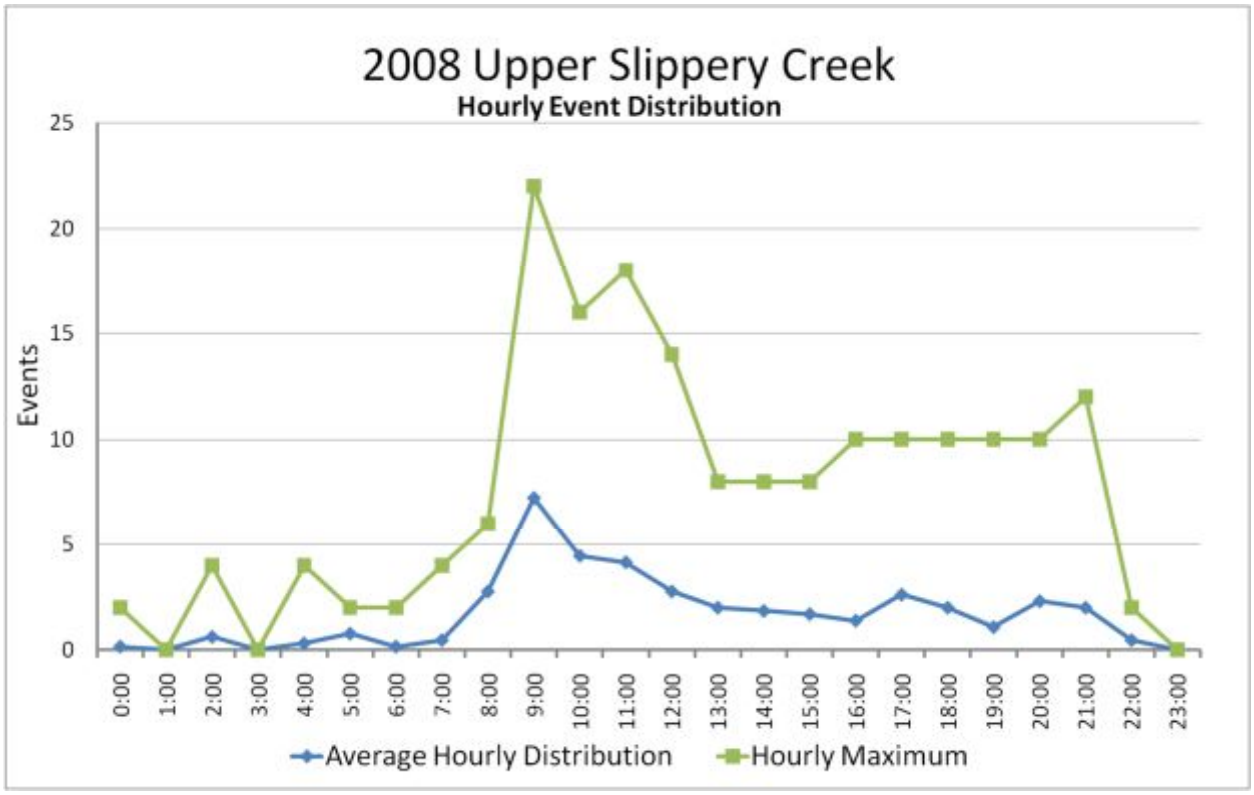


Figure 41. Hourly average and maximum for mechanized events at Upper Slippery Creek.

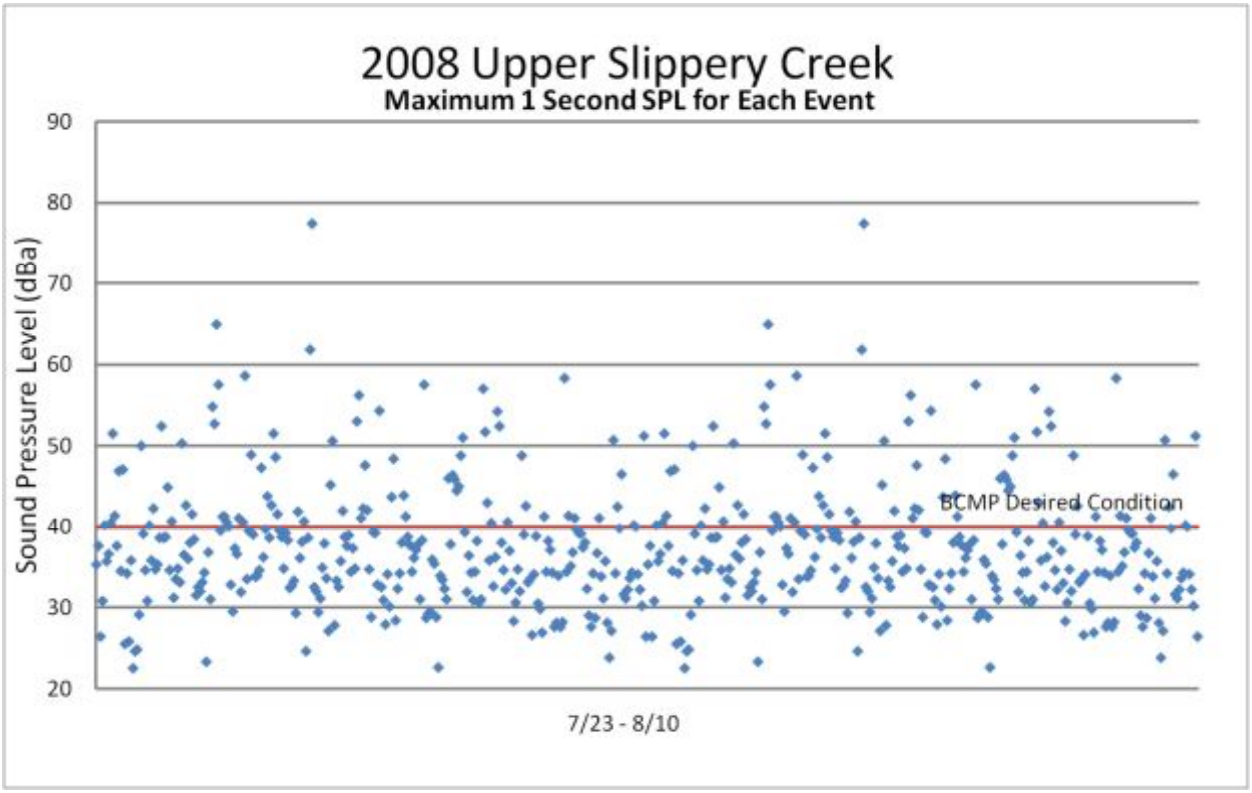


Figure 42. Maximum 1 second SPL for each mechanized event identified at Upper Slippery Creek.

Conclusion

The third year of the Denali Soundscape Inventory was intended to provide baseline natural sounds and current overflight data at an additional five sites in Denali National Park. It builds on previous work conducted 2001-2007, which collected similar data at other locations.

The acoustic monitoring systems collected detailed records of ambient sound pressure levels. The existing ambient (L_{50}) level is the median sound level, and is the composite of all sounds at a site, both human-caused and natural. Overall, all the locations sampled experienced relatively low ambient sound levels, with all sites averaging an L_{50} of less than 29dBa except the Tokositna Toe site, which was located close to a fast moving river and measured 41dBa on average. All sites exhibited some level of exceedence of the Denali Backcountry Management Plan standards as shown in the above figures. These overall findings have been added to the parkwide backcountry management plan compliance maps which can be found in Appendix B.

Table 4. Percentage of samples exceeding BCMP sound standards

Site Name	Hourly Motorized Noise Audiblity	Motorized Noise Events/Day	Motorized Max SPL
Highpower Creek	1	40	70
Toe of Kahiltna Glacier	2	30	87
Toe of Tokositna Glacier	0	6	17
Upper Wigand Creek	23	93	40
Upper Slippery Creek	24	100	28

As it stands today, Denali National Park has one of the most extensive acoustical monitoring datasets in the National Park System. The data included in this report can be used to inform a Soundscape Management Plan, General Management Plan, Resource Stewardship Strategy, Natural Resource Conditions Assessment, other park plans, or NEPA documents that include soundscapes.

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Appendix A. Glossary of Acoustic Terms

Acoustical Environment
The actual physical sound resources, regardless of audibility, at a particular location.

Amplitude
The instantaneous magnitude of an oscillating quantity such as sound pressure. The peak amplitude is the maximum value.

Audibility
The ability of animals with normal hearing, including humans, to hear a given sound. Audibility is affected by the hearing ability of the animal, the masking effects of other sound sources, and by the frequency content and amplitude of the sound.

dBA
A-weighted decibel. A-Weighted sum of sound energy across the range of human hearing. Humans do not hear well at very low or very high frequencies. Weighting adjusts for this.

Decibel (dB)
A logarithmic measure of acoustic or electrical signals. The formula for computing decibels is: 10(Log10(sound level/reference sound level)). 0 dB represents the lowest sound level that can be perceived by a human with healthy hearing. Conversational speech is about 65 dB.

Extrinsic Sound
Any sound not forming an essential part of the park unit, or a sound originating from outside the park boundary.

Frequency
The number of times per second that the sine wave of sound repeats itself. It can be expressed in cycles per second, or Hertz (Hz). Frequency equals Speed of Sound/ Wavelength.

Hearing Range (frequency)
By convention, an average, healthy, young person is said to hear frequencies from approximately 20Hz to 20000 Hz.

Hertz (Hz)
A measure of frequency, or the number of pressure variations per second. A person with normal hearing can hear between 20 Hz and 20,000 Hz.

Human-Caused Sound
Any sound that is attributable to a human source.

Intrinsic sound
A sound which belongs to a park by its very nature, based on the park unit purposes, values, and establishing legislation. The term "intrinsic sounds" has replaced "natural sounds" in order to incorporate both cultural and historic sounds as part of the acoustic environment of a park.

Listening Horizon
The range or limit of one's hearing capabilities. Just as smog limits the visual horizon, so noise limits the acoustic horizon.

L_{eq}
Energy Equivalent Sound Level. The level of a constant sound over a specific time period that has the same sound energy as the actual (unsteady) sound over the same period.

L_x
A metric used to describe acoustic data. It represents the level of sound exceeded x percent of the time during the given measurement period. Thus, L_{50} is the level exceeded 50% of the time (it is also referred to as existing ambient).

L_{nat}
An estimate of what the acoustical environment might sound like without the contribution of extrinsic (anthropogenic) sounds.

Masking
The process by which the threshold of audibility for a sound is raised by the presence of another sound.

Noise-Free Interval
The period of time between noise events (not silence).

Noise
Sound which is unwanted, either because of its effects on humans, its effect on fatigue or malfunction of physical equipment, or its interference with the perception or detection of other sounds (Source: McGraw Hill Dictionary of Scientific and Technical Terms).

Off-site Listening
The systematic identification of sound sources using digital recordings previously collected in the field.

Sound
Variations in local pressure that propagate through a medium (e.g. the atmosphere) in space and time.

Soundscape
Human perception of the acoustical environment.

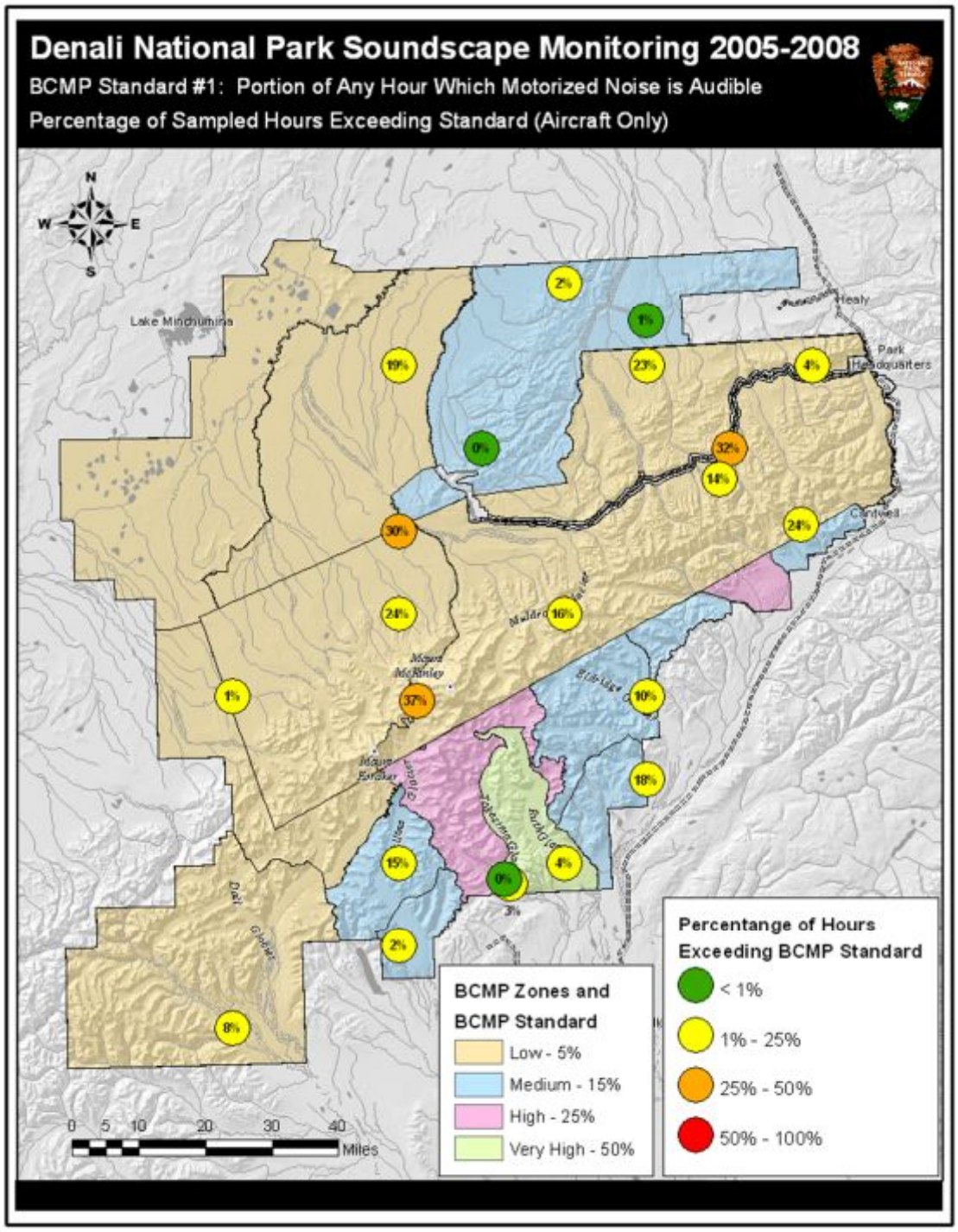
Sound Pressure
The difference between instantaneous pressure and local barometric pressure. Measured in Pascals (Pa), Newtons per square meter, which is the metric equivalent of pounds per square inch.

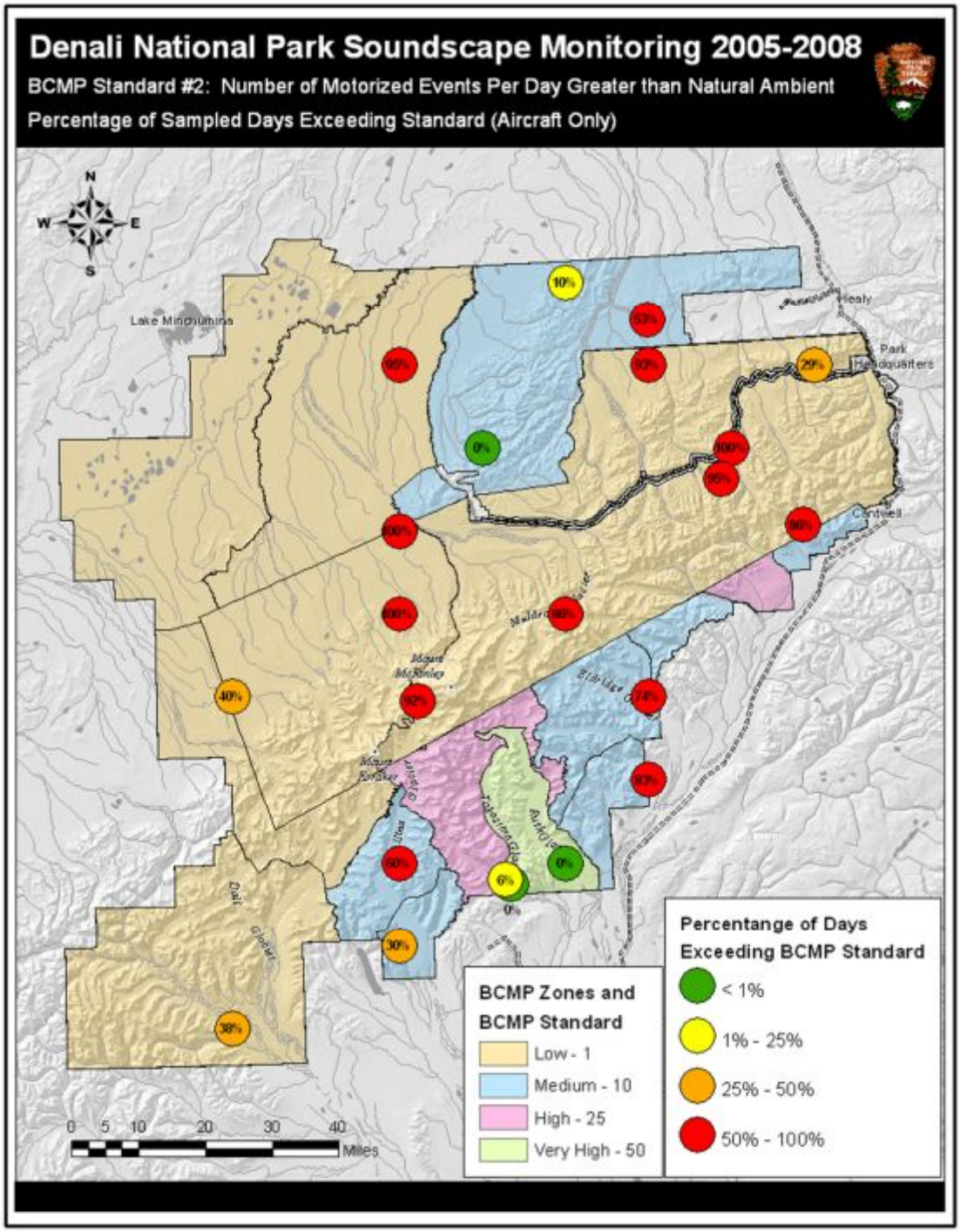
Sound Pressure Level (SPL)
A calibrated measure of sound level, expressed in decibels, and referred to an atmospheric standard of 20 micro Pascals.

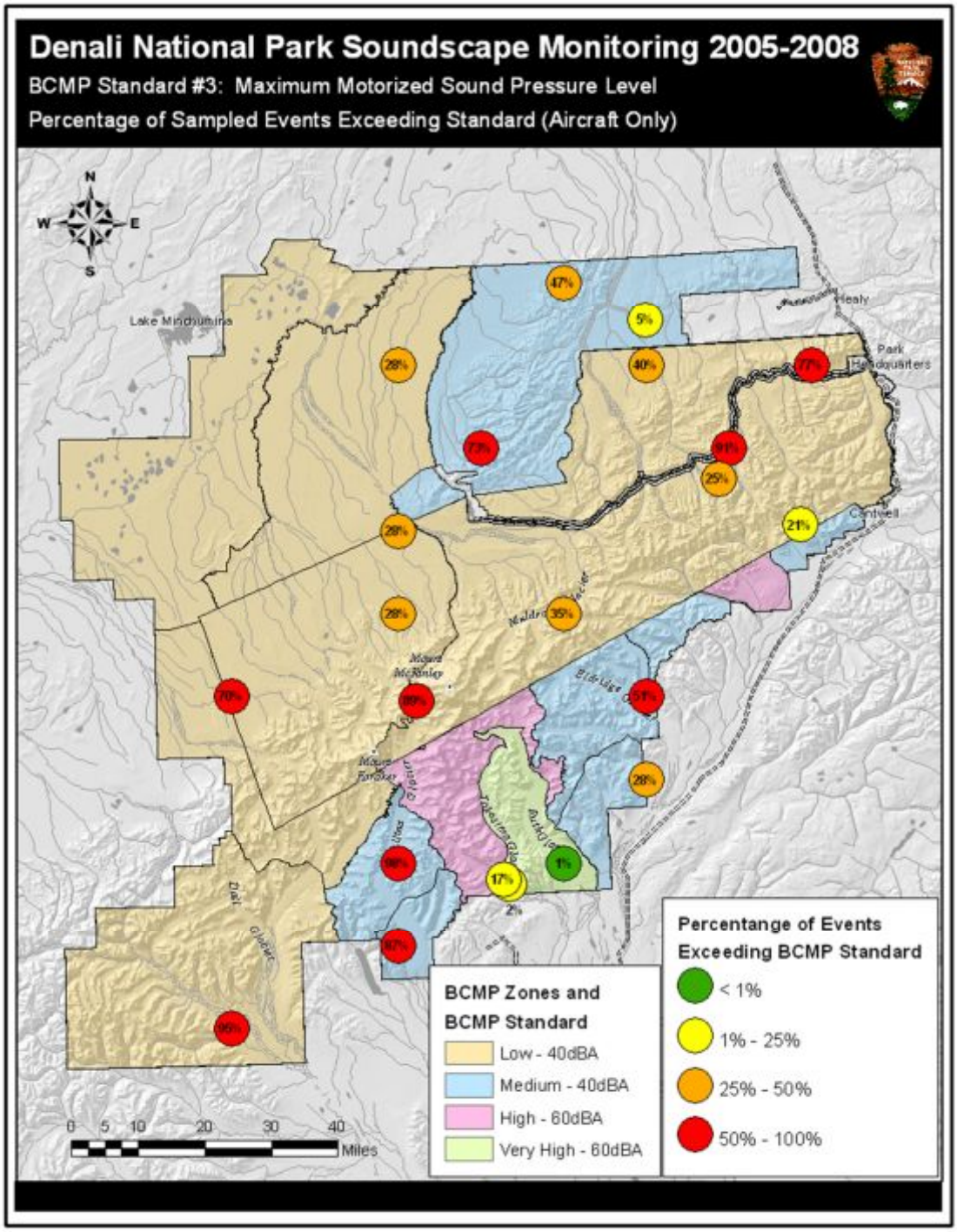
Time Audible
The amount of time that a sound source is audible to an animal with normal hearing.

Appendix B. BCMP Exceedence Maps

The following three maps are compiled to provide a parkwide look at the acoustic measurements made to date, and indicate the current level compliance with BCMP acoustic standards. There is one map for each BCMP standard, and each sampling point is annotated with the percentage of time that standard was exceeded during the measurement period.

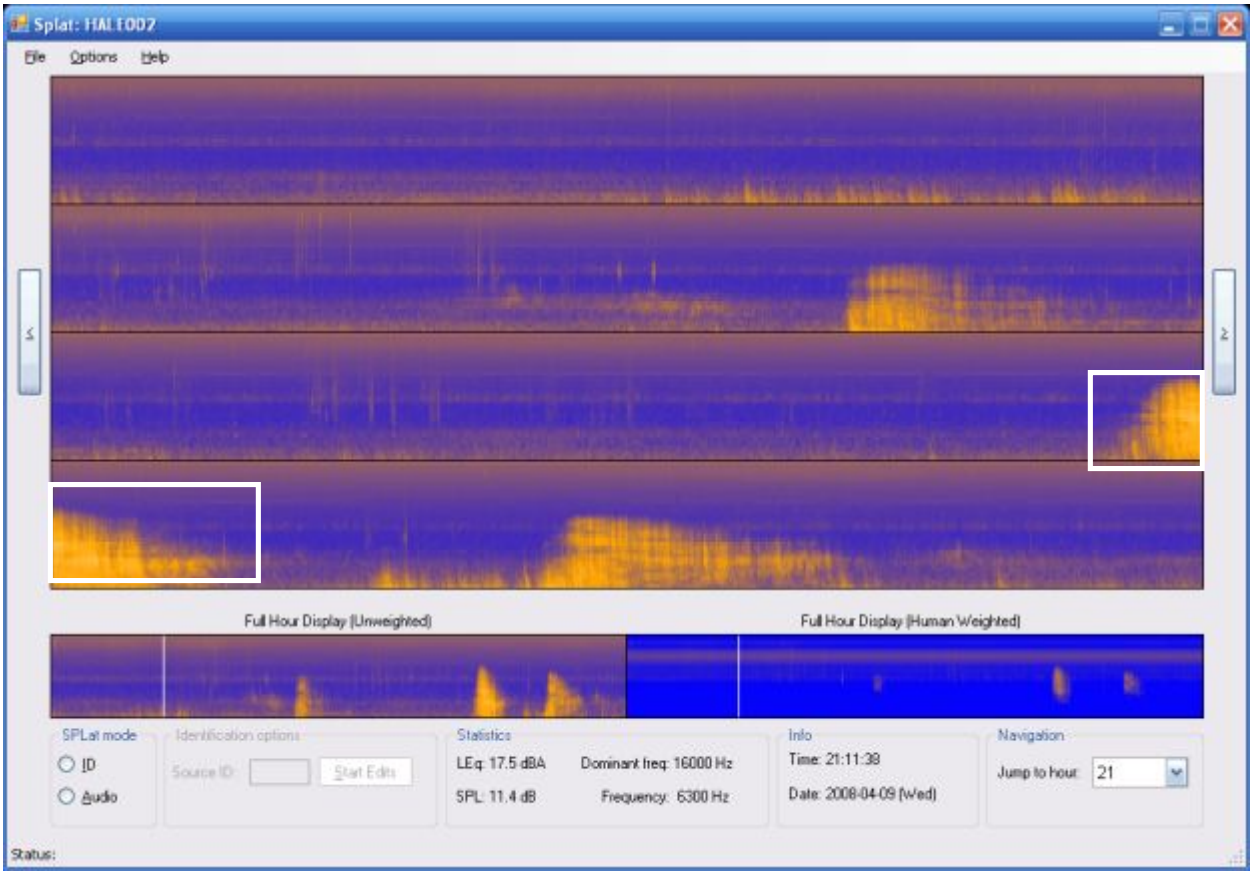



Denali National Park Soundscape Monitoring 2005-2008
BCMP Standard #2: Number of Motorized Events Per Day Greater than Natural Ambient
Percentage of Sampled Days Exceeding Standard (Aircraft Only)
N
W
E
S
Lake Minchumina
Healy
Park Headquarters
Cantwell
Mount McKinley
10%
53%
95%
93%
29%
0%
100%
95%
90%
100%
80%
40%
92%
74%
93%
60%
6%
0%
0%
30%
38%
0 5 10 20 30 40
Miles
BCMP Zones and BCMP Standard
Low - 1
Medium - 10
High - 25
Very High - 50
Percentange of Days Exceeding BCMP Standard
< 1%
1% - 25%
25% - 50%
50% - 100%


Denali National Park Soundscape Monitoring 2005-2008
BCMP Standard #3: Maximum Motorized Sound Pressure Level
Percentage of Sampled Events Exceeding Standard (Aircraft Only)
N
W
E
S
Lake Minchumina
Healy
Park Headquarters
Cantwell
Mount McKinley
47%
5%
28%
40%
77%
73%
91%
25%
28%
21%
28%
35%
70%
89%
51%
28%
98%
17%
1%
2%
97%
95%
0 5 10 20 30 40
Miles
BCMP Zones and BCMP Standard
Low - 40dBA
Medium - 40dBA
High - 60dBA
Very High - 60dBA
Percentange of Events Exceeding BCMP Standard
< 1%
1% - 25%
25% - 50%
50% - 100%

Appendix C. Analyzing audio with visual tools

Sound pressure levels (SPL) from one hour at an acoustic monitoring site at Haleakala National Park are shown below. One hour of SPL data is displayed over four rows. Each row shows SPL values from low frequency (12.5 Hz, bottom of line) to high frequency (20 kHz, top of line). Values are represented with a color scale, where dark blue is quiet and yellow/white is loud. Thus, individual events stand out against the blue background, appearing as yellow areas.



Acoustic events can be visually identified (by drawing a box around the event) and annotated. For each identified event, time, duration, maximum SPL, and spectral information are cataloged. For example, the white boxes above mark the occurrence of a high altitude jet overflight. Two other jet events are also visible.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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